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United States
Environmental Protection
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Office of Drinking Water
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Washington, D.C. 20460

EPA 570/9-84-002
December 1983

Water

EPA

# Surface Impoundment Assessment National Report

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# SURFACE IMPOUNDMENT ASSESSMENT

## NATIONAL REPORT

OFFICE OF WATER
OFFICE OF DRINKING WATER

U.S. Environmental Protection Agency

Washington, D.C. 20460

December 1983

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# FOREWORD

Preliminary studies conducted in the early 1970's indicated that the storage, treatment and disposal of liquid wastes in surface impoundments could be a significant source of contamination to ground water. Moreover, it was anticipated that as Federal and State laws governing air and water pollution were implemented, the volume of waste liquids and sludges disposed in impoundments would increase. During the same period, Congress, in passing the Safe Drinking Water Act, expressed concern about the potential effect impoundments might have on ground water. In response to this growing body of knowledge and Congressional concerns, EPA decided in 1977 to inventory impoundments and assess their potential to contaminate ground water. The Surface Impoundment Assessment (SIA) was the outcome of this decision.

The reader should note that the information which forms the basis of this report was collected by the States in 1978, 1979, and 1980. Accordingly, much of the information is dated. In particular, the discussions describing State programs reflects their status at the time the information was gathered; much has changed since. Ground water has been given increased attention in both Federal and State programs and new laws and regulations are being implemented which bring this practice under stricter controls. At the Federal level, for example, the development and implementation of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Damages, Compensation, and Liability Act (Superfund) provided national controls over the most dangerous segment of impoundments--those handling hazardous waste.

Throughout the report, we use the term "potentially hazardous waste", or "waste hazard potential." The use of "hazardous" and similar terms in this study is not identical to designated hazardous waste as used in the Resource Conservation and Recovery Act (RCRA). The SIA rating system was developed before regulations under RCRA were promulgated, and SIA waste ratings were assigned based on general industry characteristics, or on standard industrial classification codes. A more complete discussion of the SIA rating system is included as Appendix A.

Although the information is dated, the report is a valuable addition to our knowledge. It is perhaps the broadest look at the use of impoundments, and how that use may affect ground water quality. The descriptions of State programs provides an accurate picture of how States managed impoundments in the past, and provides a benchmark against which we may measure improvement.

The reader will also note that we have refrained from identifying specific facilities. The SIA does not provide meaningful data on a site specific basis. The study was designed to be a first-round approximation of contamination potentials and the assessment methodology uses secondary sources of data to perform desk-top analysis of an impoundment's potential to contaminate ground water. The data are designed to provide only a relative ranking of sites. Accurate conclusions can only be made when the data are used in aggregates that are sufficiently large to provide statistical validity. Thus, the report confines itself to general observations based on summary data.

Finally, the results of this study have been used to make a preliminary ranking of contamination potential to help the new hazardous waste protection programs assign priorities to site investigations. The data are also helping States to assess problems related to other types of impoundments which need to be addressed to protect ground water quality.

The data, which have been available since 1979, have been used extensively by both the Office of Solid Waste and the Superfund program. The Office of Solid Waste has used the data to cross check the results of the hazardous waste facilities notification, to identify non-notifiers, and to set permitting and enforcement priorities. The Superfund program used selected SIA data as a source of information for site identification, screening and investigation. More recently, the Superfund program has been seeking to assure the accuracy and comprehensiveness of its data base, and has been using data from the SIA as one tool in this effort.

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# CHAPTER I

# EXECUTIVE SUMMARY

In 1978 the Environmental Protection Agency (EPA) began a study in collaboration with the States of the magnitude and potential effects of surface impoundments on ground water quality. This effort was designed to carry out Section 1442(b)(3)(c) of the Safe Drinking Water Act (SDWA). The Agency knew that increased emphasis on air and water pollution controls resulted in an increase in sludge and waste water generation and disposal, but it had little information on the numbers, location and construction of surface impoundments or their potential for groundwater contamination. The Agency developed the Surface Impoundments Assessment (SIA) to provide more information on these issues.

Since the time the study began in 1978, several new Federal programs have come into effect with authority to protect ground water quality. The Resource Conservation and Recovery Act (RCRA) provides controls over the most important kind of impoundments, those handling designated hazardous wastes. Under this legislation, increased Federal grants have assisted many States to expand programs in this area. In addition, the enactment of the Comprehensive Environmental Damages, Compensation, and Liability Act of 1980 (Superfund) will provide resources with which to control the worst of the abandoned hazardous waste disposal sites. Although these Federal programs do not provide coverage over all impoundments, many States have expanded programs to protect ground water and to manage instances in which contamination has been detected. The findings of this study must be viewed in historical perspective. The data was collected in 1978 to 1980 and predated the increased public interest in ground water protection which began later, and the major programs initiated after 1980 as EPA and the States moved toward implementation of RCRA.

In conducting the SIA, EPA attempted to: 1) increase the Nation's data base concerning impoundments; 2) determine numbers, location and potential effects of surface impoundments on groundwater quality; 3) solicit information on existing State approaches to groundwater protection from these facilities; and 4) provide EPA with information to allow for a review of Agency programs regarding groundwater protection and surface impoundments.

The Assessment, with a few exceptions, was essentially a "desk-top study;" States used mainly secondary sources of data such as USGS maps, information from permit files, well drillers reports and other such sources in conducting both the inventory and assessment. Information on waste characteristics, for instance, was often inferred from standard industrial classification (SIC) codes rather than actual knowledge of the waste contained. In most instances, the data were not field verified by the States (or in a few States by contractors) which collected the data. The quality of the information, therefore, varies considerably from State to State. Nevertheless, the data, when used in sufficiently large aggregates and not applied to site-specific situations, characterizes the total population of surface impoundments and their potential impact on ground water quality.

The results of the study confirmed the concerns which led to its initiation. Surface impoundments, without proper siting, design, construction and operation, can threaten ground water quality. On a national level, Federal regulations and most States did not adequately address this problem in the past, although several States, including New York, California, New Mexico, New Jersey and Pennsylvania had or were developing aggressive ground water protection programs.

The data from this study have been useful to States and EPA in providing an inventory of surface impoundments and a preliminary ranking of contamination potentials with which to establish meaningful priorities for the new hazardous waste protection programs. The data will also help States to assess problems related to other types of impoundments which need to be addressed to protect ground-water quality.

The Hazardous Waste Enforcement Task force has used the data to identify high priority sites for field investigations and the Superfund Program used them as a source of information for site identification, screening and investigations. Finally, the Office of Solid Waste used the data to cross check the results of the Hazardous Waste facilities notification, to identify non-notifiers and to set permitting and enforcement priorities.

Briefly, the study was designed to locate and count as many impoundments as possible and to assess the ground water contamination potential of a significant number of the located sites. Table 1.1 provides a summary of the active sites and impoundments located in the inventory, as well as the number of sites assessed. They are presented in five major catagories: Industrial, Municipal, Agricultural, Mining, and Oil and Gas. A small number of sites have been assigned to a category termed "Other" because they do not fit any established category. For example, some States collected information on facilities which went beyond the definition of impoundment used in the national study. These "others" include such facilities as industrial septic systems, multi-family septic systems, safety impoundments around bulk storage tanks, and farm ponds used for stock watering.

### TABLE 1.1

### Summary Statistics for Located Active Surface Impoundment Sites

| Category | Located Sites* | Assessed Sites* | Located Impoundments* |
|---|---|---|---|
| Industrial | 11,760 | 8,662 | 27,912 |
| Municipal | 19,746 | 10,822 | 37,185 |
| Agricultural | 14,850 | 6,646 | 19,437 |
| Mining | 7,364 | 1,552 | 25,038 |
| Oil & Gas Brine Pits | 24,990* | 3,354 | 65,488 |
| Other | 1,553 | 350 | 5,913 |
| TOTAL | 80,263 | 31,386 | 180,973 |

* SIA site numbers for the mining and oil & gas brine pit sites are usually related to lease or field data, not to actual ownership and should not be referred to as the actual number of legal sites. The number of located impoundments would be a closer approximation for these two categories.

Located sites: Total number of facilities identified in the inventory.

Assessed sites: Total number of facilities evaluated in the inventory.

Located impoundments: Total number of impoundments identified in the inventory. The number is larger than located sites since many facilities had more than one impoundment.

## METHODOLOGY

The SIA used an evaluation methodology developed specifically to assess the potential effects of surface impoundments on ground water quality. This method assigned ratings to a site based on the following factors:

1. the permeability and thickness of the earth material above the water table (a measure of the relative rate at which liquid waste could migrate through the ground to reach the ground water);
2. the quantity of ground water available (the permeability and thickness of the aquifer);
3. the quality of the ground water (combining Step 2 and Step 3 provides a rating of the usability of the aquifer);
4. the potential hazard or toxicity of the waste (based on general industry waste characteristics-the term "hazard" and "hazardous" is not equivalent to designated "hazardous waste" under RCRA since RCRA definitions were developed after the study began);
5. the overall potential for ground water contamination (the sum of the first four steps); and
6. the potential for a nearby water supply well or surface water body to become contaminated (this involves the estimation of the flow path of contaminated ground water and whether it would intersect a well or surface water).

In addition to conducting an inventory of all known surface impoundments and conducting assessments, States provided information on impoundment bottom liners and ground water quality monitoring. States also submitted representative case studies of contamination caused by impoundments, and descriptions of their State programs.

## FINDINGS

The major findings of the study are outlined below:

### Site Selection

- Unsaturated Zone;

  Nearly 50 percent of all sites are located over unsaturated zones that are either very thin or very permeable. Such siting, given improper design, construction and/or operation, may allow leachate to attenuation of contaminants. For industrial sites, over 50 percent are so sited.

- Saturated Zone;

  Approximately 70 percent of all sites are located over thick and very permeable aquifers that allow relatively rapid movement of any plumes that may develop. For the industrial category, the percentage rises to nearly 80 percent.

- Total Hydrogeologic Setting;

  Approximately 30 percent of the sites are located in areas that have thin or permeable unsaturated zones, and overlie highly transmissive aquifers containing water that is currently used or of high quality. These sites provide the least natural protection to ground water quality. For the municipal and industrial categories, the percentage of sites so located rises to approximately 40 percent. Only about 7 percent of all sites appear to be located in areas which have hydrogeologic settings that offer the maximum protection from ground water contamination.

- Proximity to Potential Water Supplies;

  Less than 2 percent of the sites are located in areas where there is no drinking water within 1 mile, or where the water contains in excess of 10,000 parts per million total dissolved solids (>10,000 ppm TDS).

## Waste Characteristics

- Approximately 15 percent of all sites (excluding oil and gas related facilities) contain waste which may be considered hazardous as the term is used in the SIA (e.g. hazard rating in excess of 6. See Appendix A for an explanation of the rating system.). In the industrial category, about a third of the sites contain potentially "hazardous waste." The SIA used general industry waste characteristics or SIC codes to assign waste ratings. Thus, "hazardous," as used in the SIA, does not correspond directly to designated "hazardous waste" under RCRA.

## Ground-Water Protection

- As previously mentioned, nearly half of the sites assessed are located over unsaturated zones that afford little protection to ground water supplies.

- Approximately 30 percent of the industrial sites are lined. There is little or no apparent correlation between the type of waste, the siting characteristics and the use of liners.
- In addition, data on monitoring show little apparent correlation between the potential for aquifer contamination and the use of monitoring wells.

## State Programs

The State staff conducting the SIA provided information on the State programs and, in most instances, conclusions and recommendations relative to the programs. It is important to note that these conclusions primarily reflect State staff opinions, and not necessarily official State views. Moreover, these data represent the status of State programs at the time of the assessment which began in 1978, and many States have revised ground water related programs since that time. The information and data submitted to EPA, show the following findings:

- Most States derived their statutory authority from a prohibition against "polluting the waters of the State." Although this includes ground water, the laws are generally surface water oriented.
- State regulations concerning surface impoundments generally covered only the treatment and/or discharge of waste to surface waters, not ground water.
- Only six States had developed regulations which specifically address ground water contamination from surface impoundments at the time the study was conducted.
- Despite the fact that oil and gas pits are strictly regulated and their use limited to emergency and mud pits, oil and gas pits accounted for more impoundments than any other category (approximately 65,000).

## CONCLUSIONS

The study leads to the following conclusions:

- Without proper design and siting, impoundments have a high potential for contaminating ground water.
- Treatment, storage and disposal of liquids in surface impoundments is a common practice. There were over 180,000 impoundments located in the invento[illegible].

- In general, impoundments have historically been sited and constructed without apparent regard for the protection of ground water quality.

- In the past, the practice has been virtually unregulated by the Federal government and many States from the perspective of ground-water protection. However, with the implementation of RCRA, and increased attention at the State level, sites handling designated hazardous wastes will be more strictly controlled in the future. Beyond regulatory controls, the Federal programs are providing the States with resources to help administer programs to control designated hazardous wastes and generally expand programs to protect ground water quality.

# CHAPTER II

## OVERVIEW OF THE SIA

The Environmental Protection Agency decided to conduct the Surface Impoundment Assessment (SIA) because of the findings of several preliminary studies, and as a result of Congressional concerns reflected in §1442 of the Safe Drinking Water Act. The preliminary studies indicated that the storage, treatment, and disposal of liquid wastes in surface impoundments (pits, ponds, and lagoons) may be a significant source of contamination to ground water and that the extent of the problem was unknown.

The Agency determined that an inventory and assessment of surface impoundments was required, one that was comprehensive and in line with Congressional intent as expressed in both the Safe Drinking Water Act (SDWA) and the Resource Conservation and Recovery Act (RCRA).

### SCOPE OF THE SIA

The Surface Impoundment Assessment (SIA) is a one time only inventory and hydrogeologic evaluation of the ground water pollution potential of waste pits, ponds, and lagoons funded under the SDWA.

The goals of the SIA were to study the magnitude and potential effects of surface impoundments on ground water. In order to carry out these goals, five objectives were established. These objectives were:

(1) To inventory (locate and count) the number of surface impoundments in existence in the United States and its territories.

(2) To provide a first-round approximation of the ground water pollution potential of these practices.

(3) To assist the States and EPA in developing a better understanding of the problems caused by surface impoundments.

(4) To provide a data base on which EPA and the States may develop a strategy to control or regulate pollution from these sources.

(5) To provide data for review of State and Federal authorities and to recommend legislative programs to address the problem, if necessary.

As part of determining the pollution potential, a hydrogeologic evaluation of ground water contamination which used existing data was devised. Evaluations were performed on as many randomly selected sites as time and resources permitted. The system was based in part on the system developed by Harry Le Grand. The rating gives a numerical score which indicates the relative potential for ground water contamination. Appendix A gives a detailed explanation of the rating methodology.

To provide for consistency of coverage nationwide, it was necessary to develop a uniform definition of "impoundment" and to list exclusions that were not to be included in the assessment.

The definition of a surface impoundment as used in this study is:

> A natural topographic depression, artificial excavation, or dike arrangement with the following characteristics:
>
> (1) it is used primarily for storage, treatment, or disposal of wastes in the form of fluids;
>
> (2) it may be constructed above, below, or partially in the ground;
>
> (3) it may or may not have a permeable bottom and/or sides potentially allowing contamination of ground water by infiltration of its contents.
>
> (4) it has a surface dimension greater than its depth.

The list of exclusions consists of the following:

> Farm ponds used for stock watering or for fisheries; product storage tanks; ponds related to sand and gravel operations; swimming pools; natural lakes and ponds; furrow irrigation fields; rice paddies; irrigation re-use pits; sediment control basins; borrow pits resulting in sand pit lakes; storm water basins; individual and residential septic systems; well drilling mud pits; emergency pits; steel and/or concrete wastewater treatment unit process impoundments.

These exclusions are listed because they are deemed "non-problems" or contain fluids only intermittently on an emergency basis or are so numerous as to make it unrealistic to inventory. In certain cases and for compelling reasons, some of these have been included by certain States in the "Other" category.

## METHODOLOGY OF THE SIA

### EPA Funding for the SIA

EPA made available $5,000,000 in grants to the States for the conduct of the SIA. These grant funds, made under §1442(b)(3)(C) of the Safe Drinking Water Act, P.L. 93-523, were distributed among the States by a formula which took into account ground water use, population, number of manufacturing establishments, area, oil and gas sites, and mining sites. The institutions that were granted funds to conduct the SIA are outlined below:

- EPA awarded funds for conduct of the SIA to:
  - contractors or universities in six States and Territories
  - State agencies in 49 States and Territories.
- Of the 49 State agencies which took grants, the SIA was:
  - conducted either partially or totally by subagreements with...
    - another State or Federal agency in 13 States
    - a university in five States
    - a consultant in nine States
  - conducted totally by the Grantee agency in 22 States.

The timetable for the activities of the study is included in Figure 2.1.

### State SIA Organization

State SIA grantees organized their functional units and teams to suit their own needs. The following describes how the State SIA teams were organized and how they functioned.

Figure 2.2 shows the functional responsibilities of the grantees. It demonstrates that the responsibility for conducting the SIA rested with a State agency rather than a consultant or university in the vast majority of the States.

The educational composition of the SIA teams is represented nationally by the bar graph in Figure 2.3. Although the educational backgrounds of the people who worked on the SIA involve many fields, the majority were in the fields of geology and hydrology.

## SURFACE IMPOUNDMENT ASSESSMENT SCHEDULE

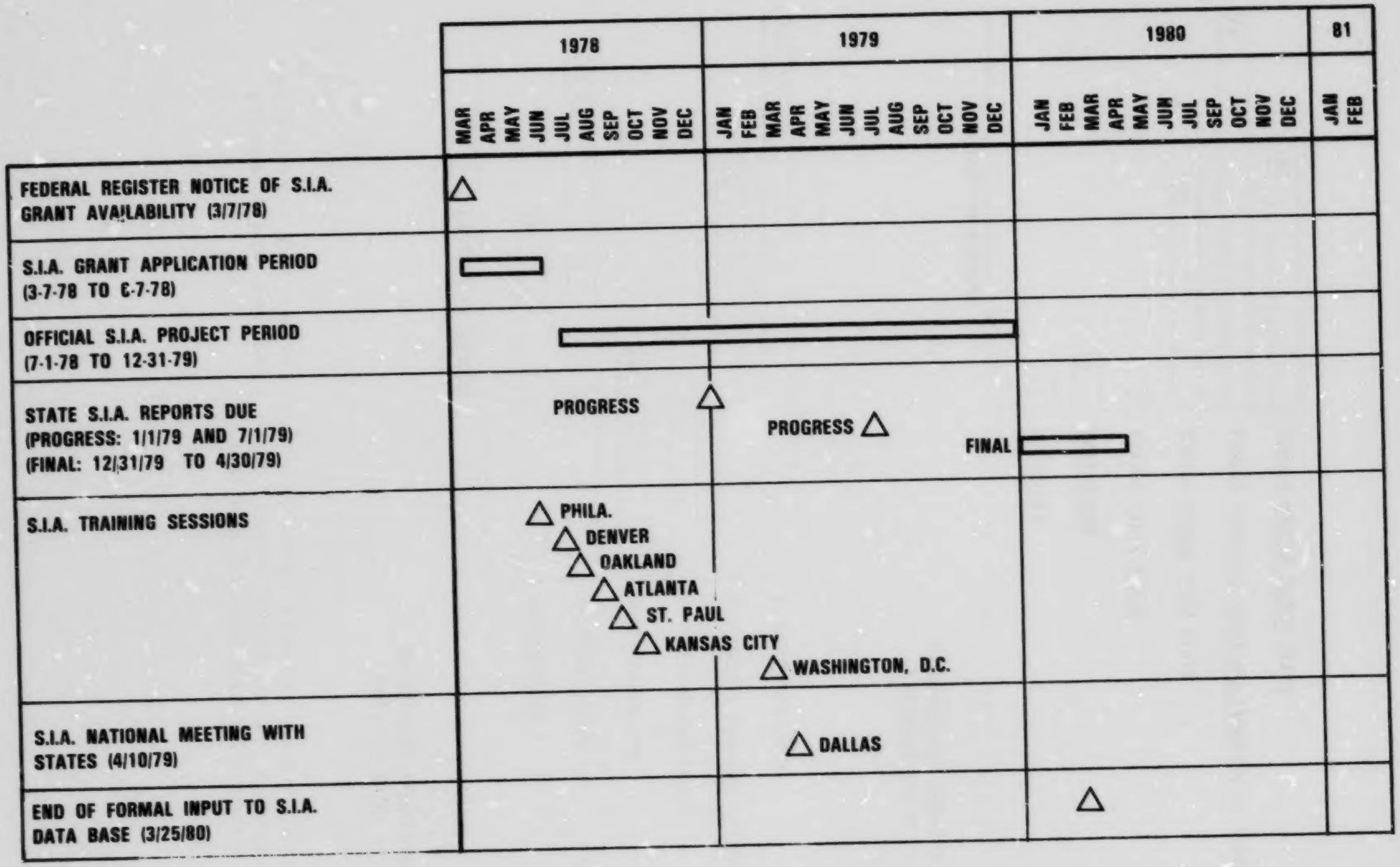


Figure 2.1

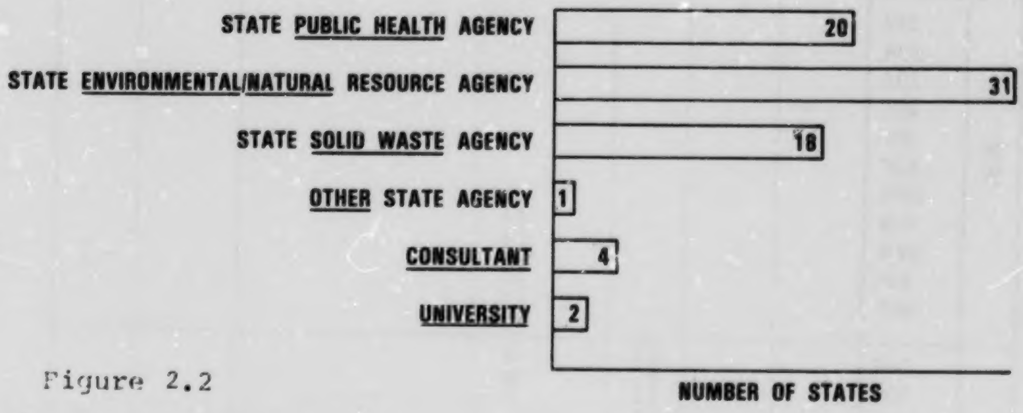


Figure 2.2

**FUNCTIONAL RESPONSIBILITY OF THE GRANTEE ***

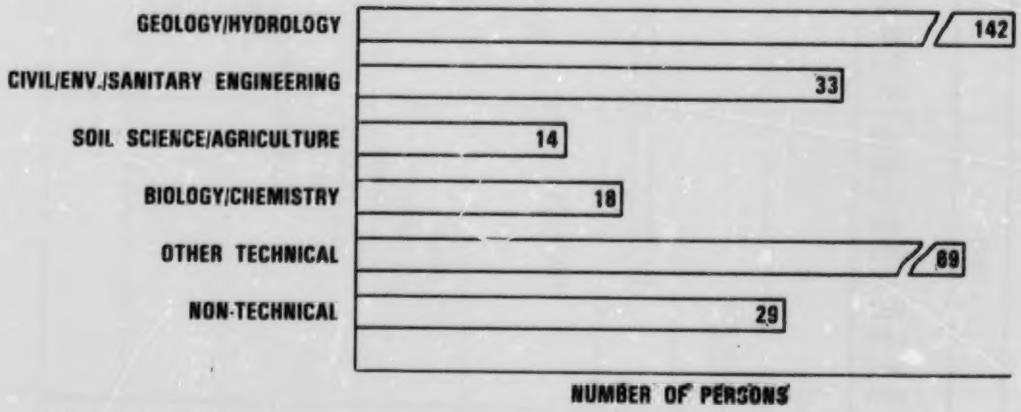


Figure 2.3

**EDUCATIONAL COMPOSITION OF THE S.I.A. TEAMS**

---

*The total exceeds the number of States and territories since, in some instances, more than one State agency worked on the SIA in a State.

## SIA TRAINING

To standardize the data collected, the SIA Work Group developed and administered training courses for the people who were to conduct the SIA in the States. This three-day training course was given seven times during the period June 1978 through February 1979.

## Coverage of the SIA

There was a random selection of the inventoried sites to identify sites to be assessed. Then within each site, a random selection was made of all impoundments to determine which impoundment should be evaluated. This random selection procedure was repeated for each category. Thus, not all sites or all impoundments within a given site were assessed. Some States assessed all sites located; other assessed every impoundment located. As a result, it is difficult to make meaningful comparisons between States on a national level on the total number of impoundments. Figure 2.4 shows the percentage of located sites which are assessed.

When considering impoundments alone, independent of sites, it is significant to note the reasonably wide distribution of assessed impoundments as a percentage of located impoundments. Figure 2.5 shows the statistics on percentage of located impoundments which were assessed. Nationally, 80,263 sites were located and 39 percent or 31,386 of them were assessed. However, 180,973 impoundments were located and 21 percent or 38,089 of them were assessed. The Location and Count phase consisted of "finding" and "inventorying" as many surface impoundments as was reasonably possible by any legal means available to the State SIA Teams. The sources of data varied from State to State as did the State's best estimate of what percentage of all sites were located (see Figure 2.6).

## HYDROGEOLOGIC EVALUATION METHODOLOGY

One of the primary objectives of the SIA was to provide a first-round approximation of the ground water pollution potential of surface impoundments. The system was not designed to discover if contamination had indeed actually occurred. Such detailed studies could logically follow the SIA with priority given to those sites having high contamination potentials. The steps used in this system are outlined in Figure 2.7. The SIA Manual for Evaluating Contamination of Potential of Surface Impoundments is reprinted in Appendix A. Figure 2.8 illustrates the sources of data used in this study. Here are some of the more common sources listed as "Other":

- Well Drillers Logs
- County Governments - i.e. Sanitarians

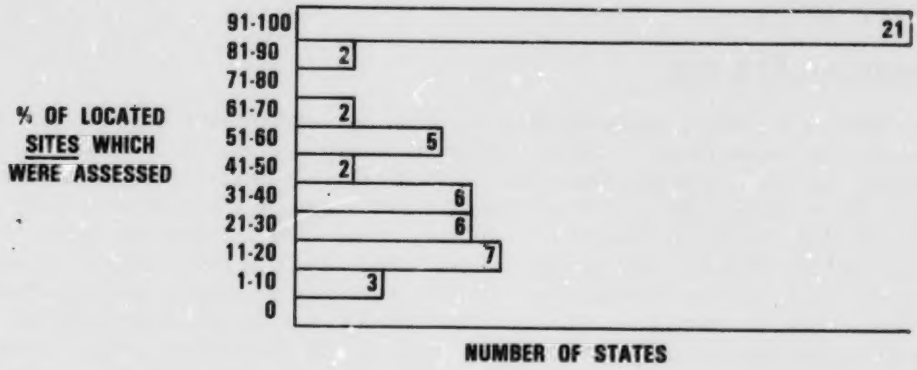


Figure 2.4

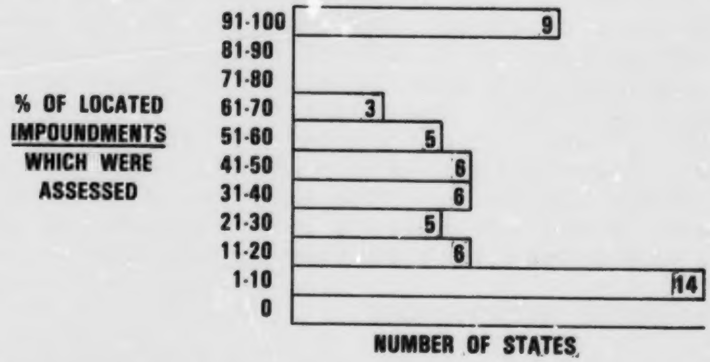
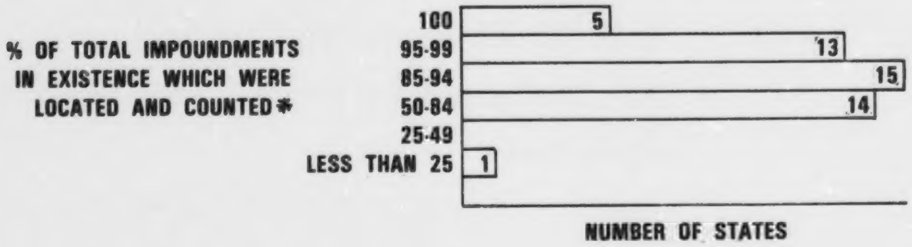


Figure 2.5



*Not all States estimated the % of total impoundments located

Figure 2.6

## EVALUATION SCHEME

STEP 1: Rate the Unsaturated Zone

STEP 2: Rate the Ground Water Availability

STEP 3: Rate the Ground Water Quality

STEP 4: Rate the Waste Hazard Potential

STEP 5: Sum Up Overall Ground Water Comtamination Potential

Step 1 + Step 2 + Step 3 + Step 4

STEP 6: Rate the Potential Endangerment to Water Supplies

Figure 2.7

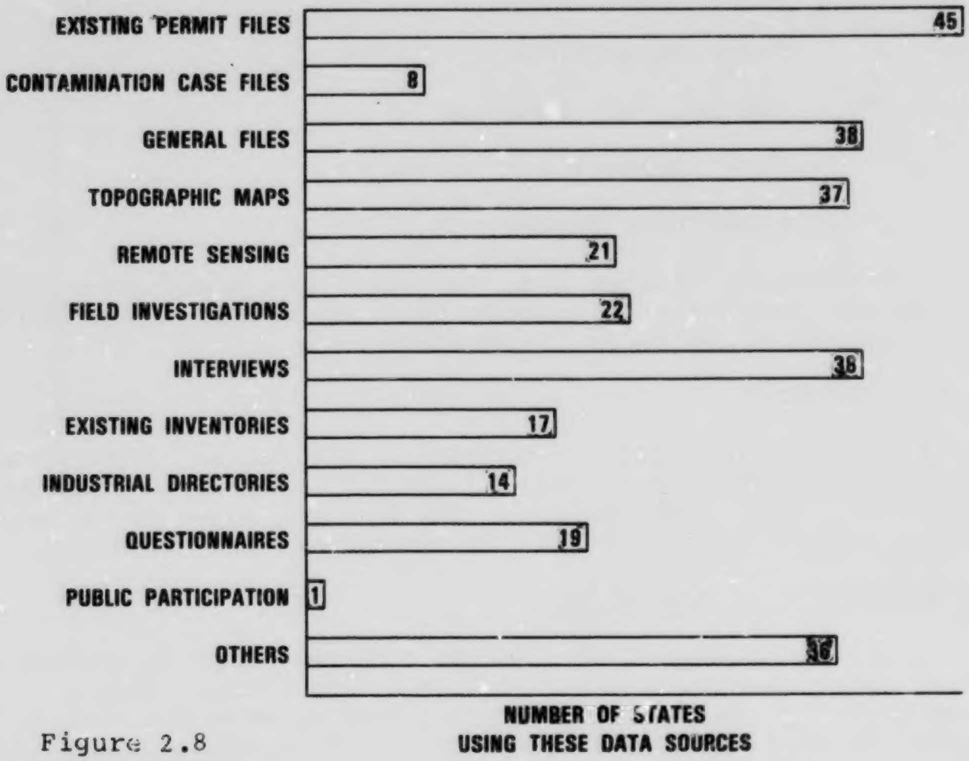


Figure 2.8

SOURCES OF DATA

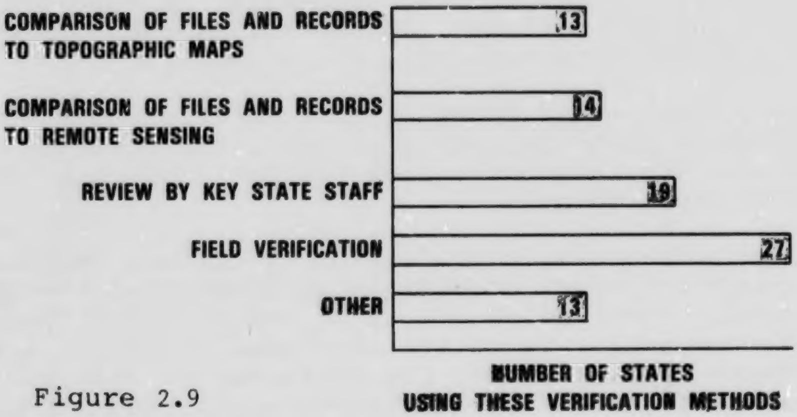


Figure 2.9

VERIFICATION METHODS

9

- U.S. Geological Survey Reports
- Soil Conservation Service Reports/Soil Surveys
- River Basin Plans
- Dairy Inspectors
- Chambers of Commerce
- "208" Reports and Surveys
- Consultant Reports

Since the data sources were largely "desk top," many States employed verification methods to confirm the data collected. Figure 2.9 illustrates the methods used.

## DATA HANDLING

EPA made the decision to develop a centralized ADP system at Washington which could handle all of the States' data at no cost to them. EPA developed the Surface Impoundment Assessment Information System (SIAIS) on IBM System 2000 software.

### Limitations of the Study

The SIA was designed to provide a first round approximation of the contamination potential of surface impoundments. The methodology, funding, and rating system were not designed to provide data that would prove valid on a site-specific basis. Nevertheless, the data, when used in sufficiently large aggregates, can establish the nature and extent of the potential impact on ground water from surface impoundments.

Funding limitations dictated that priorities be established for the inventory and assessments. Consequently, the comprehensiveness and accuracy of the data vary across categories.

Phase I, the Location and Count of Surface Impoundments, was given the highest priority. At a minimum, the State SIA Teams were to exhaust all reasonable possibilities to locate and count surface impoundments.

Phase II, the Hydrogeologic Evaluation of Surface Impoundments, was to be conducted after completion of Phase I with whatever funds remained. Under Phase II, if it was presumed that there would be more impoundments to evaluate than could be paid for with the remaining funds, then the State was to conduct hydrogeologic evaluations on one randomly selected impoundment at randomly selected sites. Funds were to be divided among the several categories of impoundments as follows:

(1) The evaluation of oil and gas sites should not receive more than 5 percent of the remaining funds;

(2) The evaluation of mining sites should receive not more than 5 percent of the remaining funds;

(3) The evaluation of industrial sites should receive at least 50 percent but not more than 80 percent of the remaining funds;

(4) The evaluation of municipal sites should receive a minimum of 10 percent of the remaining funds;

(5) The evaluation of agricultural sites should receive a minimum of 10 percent of the remaining funds.

The rating system emphasized existing data sources and is essentially a desk top study. Depending on the State, there was little or no field verification of the data collected. Accordingly, when viewed on an individual site basis, inconsistencies occur such as waste ratings which either underrate or overrate the waste hazard potential, or identification of sites as active that are closed or abandoned.

Although there was a training program developed and guidances issued on a continual basis, the States varied their approach to the study. To the degree that the rating system and training allowed for subjective interpretation, efforts between individual States were not consistent in their waste rating scores, in the priority they assigned to assessing the various categories of impoundments, or in the sources and interpretations used to conduct the hydrogeologic evaluation. Moreover, the quality of State ground water programs varies considerably, and the availability and comprehensiveness of the data vary accordingly. This limited the uses to which the data could be put.

The waste hazard score, as used in the SIA, is an approximation of the hazard potential that is based either on Standard Industrial Classification Codes (SIC) or a general waste identification. It is important to note that this method of classifying waste, while reliable for large numbers of sites viewed in aggregate, can result in errors on a site specific basis. For example, an impoundment at a facility with SIC code classification of 28 (chemical products) without further analysis would receive a relatively high hazard rating. However, it is conceivable that upon further investigation such an impoundment might be found to contain cooling water, not chemical wastes. Because the study was a first round approximation conducted without extensive field verification, it was not always possible to determine what waste an individual impoundment contained. The limited field verification that was performed suggests that while the extent may vary from State-to-State, such "misscores" are the exception, not the rule.

The term "hazardous," as used in the SIA, is not synonomous with "hazardous waste" as used in RCRA since that definition was developed after this study. In addition, wastes were assigned hazard values based on five parameters: toxicity, mobility, persistence, volume, and concentration. As a result, facilities which produce extremely high volumes of waste, such as mining operations, could receive a waste hazard rating equal to a site which produces relatively little waste of a higher toxicity.

# CHAPTER III

# STATE REGULATORY CONTROLS

## AGENCY ORGANIZATION AND AUTHORITY

### INTRODUCTION

One of the objectives of the SIA was to collect information on State programs dealing with surface impoundments in particular and ground water in general. Accordingly, EPA asked Sta[illegible] describe their laws, regulations, institutions, funding, and the general efficacy of their programs and regulatory activities that affect surface impoundments. This chapter is based on the results of these self-assessments. Although the information that follows represents the status of State programs as described by State personnel, there were often differences of opinion within individual State agencies concerning the effectiveness of programs. As a result, the characterizations of programs provided in this chapter may not reflect official State views.

In addition, many changes in State programs have resulted since the time of the study (1978-1979) due to the increased concern about ground water protection at the State level and the passage and implementation of Federal programs under RCRA, the Superfund and the Safe Drinking Water Act.

### LEGISLATIVE BASIS

At the time of the study few States had laws relating specifically to ground-water contamination from surface impoundments. More often, States derive their statutory authority from broad mandates against polluting the "waters of the State." In the majority of instances, State laws were formulated primarily with surface water protection in mind. In some cases States had laws which specifically related to only one type of impoundment or laws that provided different levels of control for different types of impoundments.

For example, one State had six different agencies empowered under distinct acts which assigned authority over various types of operations. California, on the other hand, uses the Porter-Cologne Act as the primary basis for establishing specific standards for water quality control plans, waste discharge, and disposal of liquid waste. A single State agency, the State Water Resources Control Board (in conjunction with the 9 Regional Water Quality Control Boards) had the primary responsibility for administering this and other ground water-related legislation.

Several States indicated they were in the process of developing new, more stringent legislation that addressed ground water specifically. This was largely a result of recent Federal legislation and increased demand for good quality water. Hawaii, for example, was developing a State water code which requires the following: (1) review of all water quality programs, (2) establish agency responsibilities, (3) streamlined regulatory processes, (4) establish guidance on water rights.

Table 3.1 is an overview of State authorities at the time of the survey. With regard to enabling legislation, most State programs did not specifically address ground water pollution from surface impoundments. As discussed earlier, States derived their statutory authority from broad mandates against polluting the "waters of the State." Where legislation addressed surface impoundments, it generally focused on point source discharges to surface water rather than seepage and non-point pollution.

## STATE REGULATORY PROGRAMS

A majority of the States surveyed had some sort of regulatory program involving a permitting system for waste impoundments under either State or Federal programs. In the States which practice permitting and licensing (see Table 3.1) of surface impoundments, the focus of the program was frequently directed on the treatment phase of the entire facility, or on the direct discharge of wastes to surface water through the NPDES program and not on ground water contamination. However, a few State programs (New Mexico, Connecticut, New Jersey, New York, Pennsylvania, and California) concerned themselves directly with the discharge of wastes to the ground water.

However, most State programs--whether they addressed facility standards and direct discharges or whether they were empowered to permit indirect dischargers--reported that they were not adequately staffed and funded to provide the comprehensive plan reviews, regular inspections, effective monitoring programs, and consistent, timely enforcement actions required to assure compliance with permit conditions.

Enforcement of permit requirements and pollution controls, for example, was subject to the effects of limited resources. Approximately half the States reviewed construction plans prior to issuing a permit, but only nine States regularly inspected facilities, and even these inspections were reported to be sporadic due to time and staff constraints.

Over 50% of the States could require a new operator to monitor his facility in some manner. However, again resource constraints limited both the number of sites at which monitoring was actually required and the efficiency of any State review of monitoring

## TABLE 3.1

## STATE AUTHORITIES

| STATE | LEAD AGENCY(S) | Statutory Law | Rules/ Regulations | License/ Permit | Plan Review | Inspection | AGR | MUN | IND | OAG | MNG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alabama | Alabama Geological Survey | | | | | | | | | | X |
| | Water Improvement Comm. | | | | X | | X | X | X | | |
| | Dept. of Public Health | | | | | | X | X | X | | |
| | State Oil & Gas Board | | | | | | | | | X | |
| Alaska | Dept. of Env. Conser. | X | | X | X | X | | X | X | X | |
| American Samoa | Dept. of Health, Dept. of Public Works | | | | | | | X | | | |
| Arizona | Dept. of Health Services (11 Other Agencies included) | X | X | X | X | X | X | X | X | X | X |
| Arkansas | Dept. of Pollution Control and Ecology | X | X | X | X | | X | X | X | X | X |
| | State Health Dept. | | | | | | | X | | | |
| California | Resources Agency DWR, WRCB, RWQB | X | X | X | X | X | X | X | X | X | X |
| Colorado | Water Quality Control | X | X | X | | | | X | | | X |
| | O&G Conservation Comm. | X | X | | | | | | | X | |
| | Div. of Mined Land Reclamation | | | | | | | | | | |
| | Dept. of Natural Resources | X | X | | | | | | | | X |
| Connecticut | Dept. of Environmental Protection | X | X | X | | | X | X | X | | |

TABLE 3.1 (Cont'd)

STATE AUTHORITIES

| STATE | LEAD AGENCY(S) | Statutory Law | Rules/ Regulations | License/ Permit | Plan Review | Inspection | AGR | MUN | IND | OAG | MNG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Delaware | Div. of Env. Control | | | | | | | | | | |
| | Dept. of Health & Social Services | X | X | X | X | | | X | X | | |
| District of Columbia | | | | | | | | | | | |
| Florida | Dept. of Env. Regulation | X | X | X | X | X | | X | X | X | X |
| Georgia | Dept. of Natural Resources, Environmental Prot. Div. | X | X | | X | | X | X | X | | X |
| Hawaii | Dept. of Health | X | X | X | X | | X | X | X | | |
| Idaho | Dept. of Health & Welfare | | | | | | | | | | |
| | Div. of Environment | X | | | X | | X | X | X | | X |
| | Dist. Health Dept. | | | X | | | X | X | | | |
| | Dept. of Water Resources | | | | | | | | | | |
| | Soil Conservation Com. | | | | | | X | | | X | |
| | Dept. of Lands | | | | | | | | | | |
| Illinois | Env. Protection Agency | X | X | | | X | X | X | X | | |
| | Dept. of Mines & Minerals | X | | X | | | | | | X | X |
| Indiana | Board of Health | | | | | | | | | | |
| | Stream Pollution Control Board | X | | X | | | | | | | |
| | Water Pollution Control Div. | | X | | X | X | X | X | X | | X |
| | Water Supply Section | | X | | X | X | | X | | | |
| | General Sanitation section | | X | | X | X | | X | | | |
| | Solid Waste Management Section | | X | | X | X | | | | | |
| | Dept. of Natural Resources | X | | X | | | | | | | |
| | Reclamation Division | | X | | X | X | | | | | X |
| | Oil and Gas Division | | X | | X | X | | | | X | |

TABLE 3.1 (Cont'd)

STATE AUTHORITIES

| STATE | LEAD AGENCY(S) | Statutory Law | Rules/ Regulations | License/ Permit | Plan Review | Inspection | AGR | MUN | IND | OAG | MNG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Kansas | Dept. of Health & Environment<br>Div. of Environment | X | X | X | X | X | X | X | X | X | X |
| Kentucky | Dept. of Natural Resources & Environmental Protection | X | X | X | X |  | X | X | X | X |  |
| Louisiana | Office of Env. Affairs | X | X | X |  | X |  | X | X |  |  |
|  | Dept. of Natural Resources | X |  |  |  |  |  |  |  | X | X |
|  | Dept. of Agriculture | X |  |  |  |  | X |  |  |  |  |
| Maine | Dept. of Env. Protection | X | X | X | X |  |  | X | X | X |  |
| Maryland | State Water Res. Adm. | X |  | X |  |  | X | X | X |  |  |
|  | Env. Health Adm. | X |  |  |  |  |  | X |  |  |  |
|  | Maryland Bureau of Mines | X | X |  |  |  |  |  |  |  | X |
| Massachusetts | Water Resources Commission | X |  | X |  |  |  |  |  |  |  |
|  | Dept. of Env. Quality | X |  |  |  |  | X | X | X | X | X |
| Michigan | Dept. of Natural Resources | X | X | X | X | X |  | X | X | X | X |
|  | Dept. of Public Health | X | X | X | X | X |  | X |  |  |  |
| Minnesota | Pollution Control Agency | X |  | X |  | X | X | X | X |  |  |
|  | Dept. of Natural Resources | X |  |  | X |  |  |  |  |  | X |
| Mississippi | Dept. of Natural Resources | X | X | X |  |  | X | X | X |  |  |
|  | Oil and Gas Board | X |  |  |  |  |  |  |  | X |  |
|  | Board of Health | X |  |  |  |  |  |  | X |  |  |
| Montana | Dept. of Health & Env. Sciences | X | X | X |  |  |  | X | X |  | X |
|  | Oil & Gas Conservation Div. | X | X |  |  |  |  |  |  | X |  |
|  | Dept. of State Lands |  |  | X | X |  |  |  |  |  | X |

TABLE 3.1 (Cont'd)

STATE AUTHORITIES

| STATE | LEAD AGENCY(S) | Statutory Law | Rules/ Regulations | License/ Permit | Plan Review | Inspection | AGR | MUN | IND | OAG | MNG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nebraska | Dept. of Env. Control | X | X | X | X |  | X | X | X |  |  |
|  | O&G Conservation Comm. | X | X | X |  |  |  |  |  | X |  |
| Nevada | Dept. of Env. Protection | X |  | X |  |  | X | X | X |  |  |
| New Hampshire | Water Supply & Pollution Control Commission | X |  | X | X |  | X | X | X |  |  |
|  | Dept. of Health & Welfare | X |  | X |  |  |  | X | X |  |  |
| New Mexico | Env. Improvement Division |  | X | X | X |  | X | X | X | X | X |
|  | Oil Conservation Division | X | X | X |  | X |  |  |  | X |  |
|  | Coal Surface Mining Bureau | X | X |  |  |  |  |  |  |  | X |
| New York | Dept. of Env. Conservation |  | X | X | X | X |  | X | X | X |  |
| North Carolina | Dept. of Natural Resources & Community Development | X |  | X | X |  | X | X | X |  | X |
|  | Dept. of Human Resources | X |  |  |  |  |  |  | X |  |  |
| North Dakota | Dept. of Health | X | X | X | X | X | X | X | X |  |  |
|  | Geological Survey | X |  | X |  |  |  |  |  | X | X |
|  | Public Service Commission |  | X |  | X |  |  |  |  |  |  |
| Ohio | EPA | X | X | X | X |  | X | X | X |  |  |
|  | Dept. of Natural Resources |  | X |  |  | X |  |  |  | X | X |
| Oklahoma | Corporation Commission | X | X |  |  |  |  |  |  | X |  |
|  | Dept. of Health | X | X |  |  | X | X |  | X |  |  |
|  | Water Resource Board | X | X | X |  |  | X | X | X |  |  |
|  | Dept. of Agriculture | X |  | X |  |  | X |  |  |  |  |
|  | Dept. of Mines | X |  |  |  |  |  |  |  | X |  |
| New Jersey | Dept. of Env. Protection |  |  |  |  |  |  |  |  |  |  |
|  | Dept. of Water Resources | X | X |  | X |  |  | X | X |  |  |

TABLE 3.1 (Cont'd)

STATE AUTHORITIES

| STATE | LEAD AGENCY(S) | Statutory Law | Rules/ Regulations | License/ Permit | Plan Review | Inspection | AGR | MUN | IND | OAG | MNG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oregon | Dept. of Env. Quality | X | X | X | X |  | X | X |  |  | X |
|  | Dept. of Geology & Mineral Ind. | X |  | X |  |  |  |  |  | X |  |
| Pennsylvania | Bureau of Water Quality Management | X | X | X | X | X | X | X | X | X | X |
|  | Bureau of Surface Mine Reclamation | X |  |  |  |  |  |  |  |  | X |
|  | Bureau of Topographic & Geologic Survey | X |  |  |  |  |  |  |  | X |  |
| Puerto Rico | Aqueduct & Sewer Auth | X |  |  |  |  |  | X |  |  |  |
|  | Env. Quality Board | X |  |  |  |  |  | X | X |  |  |
|  | Dept. of Health | X |  |  |  |  | X | X | X |  |  |
| Rhode Island | Dept. of Env. Management | X | X | X | X |  |  |  | X |  |  |
| South Carolina | Dept. of Health & Env. Control | X |  | X | X | X | X | X | X |  |  |
| South Dakota | Office of Water Quality | X |  |  | X |  | X | X | X |  | X |
| Tennessee | Div. of Water Quality Control | X |  | X |  |  |  | X | X |  |  |
|  | Div. of Solid Waste Mgmt. | X | X |  |  |  |  |  | X |  |  |
| Texas | Dept. of Water Resources | X | X | X | X | X | X | X | X |  | X |
|  | Railroad Comm. |  | X |  |  | X |  |  |  | X | X |
| Utah | State Dept. of Health | X | X |  | X |  |  | X | X | X | X |
| Vermont | Agency of Env. Conservation | X |  | X | X |  |  | X | X |  |  |

TABLE 3.1 (Cont'd)

STATE AUTHORITIES

| STATE | LEAD AGENCY(S) | Statutory Law | Rules/ Regulations | License/ Permit | Plan Review | Inspection | AGR | MUN | IND | OAG | MNG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Virginia | State Water Control Board | X | X | X | | | | X | X | X | |
| | State Dept. of Health | X | X | | | | | X | | | |
| Washington | Dept. of Ecology | X | | X | | X | | X | X | | |
| West Virginia | Div. of Water Resources | X | | X | | | | | | X | |
| | Env. Health Division. | X | | | | | | X | | | |
| | Div. of Reclamation | | X | | X | | | | | | X |
| Wisconsin | Dept. of Natural Resources | X | | X | X | | | X | X | | X |
| Wyoming | Dept. of Env. Quality | X | | X | X | | X | X | X | | X |
| | O&G Conservation Comm. | | X | X | | | | | | X | |
| | Office of Ind. Siting Adm. | | X | | X | | | | X | | |

data. Frequently, facilities which existed before regulations became effective were not subject to monitoring requirements and, in many States these laws and regulations are relatively recent. As a result, many older facilities are not subject to monitoring requirements even where such requirements exist.

A few States had developed computerized data bases that were sampled for selected parameters periodically. The ultimate aim of these programs was to establish background quality so that changes can be detected.

## INSTITUTIONAL FRAMEWORK

The organization within States having responsibility for control of surface impoundments covers a broad spectrum of practices at the time of the study. In general, institutional approaches employed by the States may be characterized as single agency, lead agency with cooperating agencies, cr multi-agency. Table 3.2 illustrates the percentage of States in these categories. It appears that the majority of States fall into the multi-agency category, i.e. have several agencies involved in regulating impoundments, with no specific agency taking the lead. It is difficult to make other conclusions on a nationwide basis from this table since some States did not include sufficient information to adequately characterize their program.

Many States indicated that having several agencies involved in water pollution control in general, and surface impoundment controls in particular, can cause problems. The surface impoundment survey revealed voids and overlaps in management authority, probably resulting from the involvement of several agencies. The State agencies often competed for limited resources to accomplish similar goals.

At the time the study was conducted the legislature in Maine had authorized a Ground Water Protection Commission, and regulations were being drafted for control of hazardous waste. In Colorado, a ground-water quality task force responded to the passage of the Safe Drinking Water Act by promulgating State rules which will serve to regulate surface impoundments. With increasing attention to the control of designated hazardous waste under RCRA, many additional States are currently considering actions to improve coordination among agencies involved in ground-water protection.

Impoundments in the Agricultural category were the most consistently unregulated facilities. Most States had no program pertaining to these, other than voluntary construction requirements established by the Soil Conservation Service (SCS). After agricultural impoundments, oil and gas sites were the least regulated, particularly in the producing States in the East and Midwest. Even in the West and Southwest, where regulations

## INSTITUTIONAL APPROACHES

| | NUMBER OF STATES | PERCENT |
|---|---|---|
| Single Agency | 11 | 22% |
| Lead Agency-with Cooperating Agencies | 9 | 18% |
| Multi-Agency | 19 | 38% |
| No Data | 11 | 22% |

Table 3.2

either prohibit or severely limit the use of oil and gas impoundments, the large number of such sites in the inventory indicated that regulations were not strictly enforced.

## PERSONNEL AND FUNDING

The issue most critical to the effectiveness of State programs and most frequently mentioned by the States was funding and, as a result, staffing. In general, the States found current funding and staffing inadequate. A few States indicated that funding and staffing were taxed just to maintain present programs. Several States noted unfilled positions due to lack of funding or hiring constraints, and lack of qualified candidates.

Staffing qualifications varied from State to State but most positions dealing with ground-water contamination in general, and surface impoundments in particular, require training in hydrology or geology. However, most States had difficulty finding candidates with adequate training.

Ohio was training existing staff in ground water science and policies and was hiring persons with some ground water background. In many States, the staff had training in sanitary engineering and water chemistry, but few had specific hydrogeologic expertise. This may reflect the bias towards surface water quality. States reported that the most critical issue to hiring qualified staff obtaining adequate funding and identifying competent candidates.

## TECHNICAL DESIGN CRITERIA

Most States had established some type of technical design criteria for siting, constructing, or operating surface impoundments. Here again there was a wide disparity between States as to what was required, and often considerable difference in technical requirements between agencies of a single State. Most States applied design criteria on a case-by-case basis depending on hydrogeologic conditions, type of waste and category of impoundment, and aquifer quality and use. The technical requirements most commonly employed by the States included liners, buffer zones in the vicinity of production wells, and the use of water quality standards.

The most common technical requirement was the use of liners to prevent seepage. Liners were usually required to meet a certain maximum permeability. The use of liners as a requirement often depended on waste type. Many States also used buffer zones in the vicinity of production wells. Essentially this type of requirement is not designed to protect ground water, itself, but it does isolate areas of aquifers used as drinking water supplies from potential sources of contamination. Isolation zones prohibit siting of disposal facilities within a given distance from a well. In most cases, the distance is determined by the type of well and hydrogeologic conditions in the vicinity of the well. Distances varied considerably, with one State requiring as little as a 200 ft. buffer and another a buffer in excess of 2000 ft. While a number of States were moving towards ground-water standards, at the conclusion of the study only nine (California, Florida, Maryland, New Jersey, New York, New Mexico, Nebraska, Utah, Virginia) had done so.

Several more States were in the process of developing new regulations, or legislation which would authorize them. Still other States were developing aquifer classification schemes based on use patterns and ground water quality. Many States were developing minimum standards for impoundments which were part of a treatment chain, but since this focuses primarily on surface features, such an approach may not significantly affect ground water contamination.

## STATE ASSESSMENTS OF FEDERAL PROGRAMS

The principal Federal programs which the States discussed were the ones implemented under the Resource Conservation and Recovery Act (RCRA); the Clean Water Act (CWA); Safe Drinking Water Act (SDWA) which authorized the Underground Injection Control Program, the SIA, and the Sole Source Aquifer Program; and the Toxic Substances Control Program. There were a variety of attitudes on these programs.

For example, California found that Federal legislation and programs have had little effect on State programs because Federal guidelines were no more stringent that those of the State programs. Delaware, on the other hand, noted improvement in the State program directly attributable to Federal initiatives. Arkansas suggested that a ground-water protection program be developed in each State. On the other hand, Indiana stated that while both State and Federal programs are weak, EPA oversight is excessive. Kentucky cited excessive reporting requirements. Vermont noted a need for Federal research into the long range effects of hazardous materials on the environment and the development of uses and markets for these wastes.

The most frequent comment made by the States was the need for Federal programs to be more flexible and to acknowledge local needs of the States. South Dakota expressed a desire to see Federal programs place greater emphasis on local governments and their part in controlling ground water pollution. Several States, including Nebraska and Louisiana, noted that Federal programs do not always apply from region to region and from State to State due to variations in geology, hydrology, climate and other geographical features. Arizona pointed out a need for programs under CWA, SDWA, and RCRA to be coordinated and integrated so that the programs support one another and avoid duplication of effort. Several States noted that control is best achieved through existing or modified State programs but most required Federal funding to staff adequately and operate some existing programs and any new ones. Idaho noted that improved auditing of Federally-funded State programs to assure proper management and implementation could be the Federal government's "most valuable contribution to ensuring strong and uniform State enforcement policy."

# CHAPTER IV

# LOCATION AND COUNT

As stated in Chapter II, a total of 80,263 active and abandoned sites has been located and inventoried in the course of the SIA. These sites contain a total of 180,973* impoundments.

The inventoried sites, both active and abandoned are distributed among six categories designated as:

Municipal
Agricultural
Mining
Oil & Gas
and Other

Table 4.1 shows the nationwide distribution of sites and impoundments among these categories. Of the 80,263 sites, 31,386 were randomly chosen to be assessed as shown in Table 4.2. A State-by-State distribution of assessed sites is shown in Appendices I-IV. The assessment is described in Appendix A; it consists generally of ratings based on characteristics of the unsaturated zone, the saturated zone, the transmissivity of the aquifer, and the waste.

## LOCATION AND COUNT

### Active Sites

To provide for nationwide consistency in presenting and analyzing the results of the SIA, we reorganized some of the data provided by some States to get a uniform categorization of the sites. We based the reorganization on Standard Industrial Classification (SIC) codes to sort the data according to the original SIA instructions or the prevalent interpretation by the States. This was necessary only where States did not assign a given industrial group to the proper SIC code and, in general, States did an adequate job in identifying the correct classification code.

The relative importance, in terms of numbers, for each category is shown in Figure 4.1. Thirty-one percent of all sites, and 37% of all impoundments belong to the oil and gas category, making it the most important, in terms of numbers, in the data base. The municipal and agricultural categories come next in terms of number of located sites. The number of assessed

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*All numbers and percentages presented in this chapter reflect the numbers in the data base and represent only an approximation of the actual numbers of sites and impoundments in the various categories of data presented.

## LOCATED SITES

| | Active Sites | Active Impoundments | Abandoned Sites | Abandoned Impoundments |
|---|---|---|---|---|
| Agricultural | 14,677 | 19,167 | 173 | 270 |
| Municipal | 19,116 | 36,179 | 630 | 1,006 |
| Industrial | 10,819 | 25,749 | 941 | 2,163 |
| Mining | 7,100 | 24,451 | 264 | 587 |
| Oil & Gas | 24,527 | 64,951 | 463 | 537 |
| Other | 1,500 | 5,745 | 53 | 168 |
| TOTAL | 77,739 | 176,242 | 2,524 | 4,731 |

Total Located Sites 80,263
Total Located Impoundments 180,973

Table 4.1

## ASSESSED SITES

| | Active Sites | Active Impoundments | Abandoned Sites | Abandoned Impoundments |
|---|---|---|---|---|
| Agricultural | 6,597 | 7,133 | 49 | 49 |
| Municipal | 10,675 | 13,626 | 147 | 152 |
| Industrial | 8,193 | 10,664 | 469 | 578 |
| Mining | 1,448 | 2,045 | 104 | 105 |
| Oil & Gas | 3,304 | 3,330 | 50 | 54 |
| Other | 327 | 327 | 23 | 26 |
| TOTAL | 30,544 | 37,125 | 842 | 964 |

Total Assessed Sites 31,386
Total Assessed Impoundments 38,089

Table 4.2

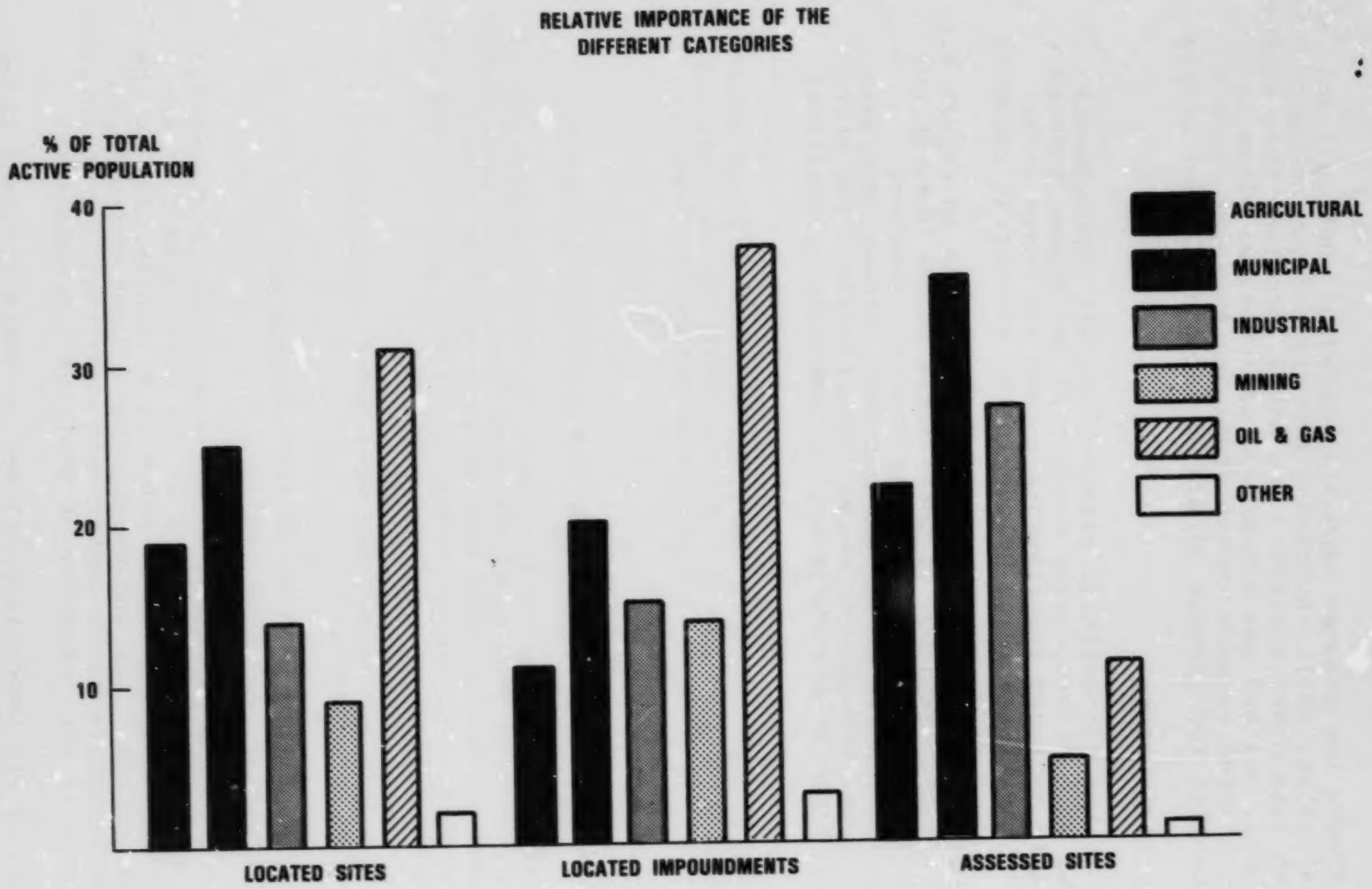

RELATIVE IMPORTANCE OF THE DIFFERENT CATEGORIES
% OF TOTAL ACTIVE POPULATION
40
30
20
10
LOCATED SITES
LOCATED IMPOUNDMENTS
ASSESSED SITES
AGRICULTURAL
MUNICIPAL
INDUSTRIAL
MINING
OIL & GAS
OTHER

Figure 4 .1

sites reflects the greater emphasis placed on municipal and industrial sites, while the mining and oil and gas category were given less consideration. The study specified this approach since mining, oil and gas sites, and agricultural sites are generally located in more remote areas and therefore have a lower potential for adverse impact on large numbers of people.

## Agricultural Category

Included in the agricultural category are all impoundments associated with farming, crop production and animal husbandry. Specifically excluded are slaughterhouses and other animal processing facilities which belong in the industrial category.

The location of the agricultural sites, depicted in Figure 4.2, shows a high concentration of these sites in the Midwest and the central and southeastern United States. Heaviest concentrations are in Minnesota, Missouri, Kansas, Nebraska, South Carolina, Georgia, Michigan, and Illinois. The States of Louisiana and Nevada chose not to inventory agricultural sites.

A breakdown by SIC codes is contained in Table 4.3 and shows that general livestock and dairy farms comprise the greatest number of sites, followed by hog farms and cattle feedlots.

## Municipal Category

Three types of facilities make up the municipal category.

1 - All domestic waste treatment facilities regardless of ownership, including municipal sewage treatment plants and privately owned facilities located at hotels, restaurants, mobile homes, parks and subdivisions (SIC code 4952).

2 - Impoundments associated with water treatment facilities (SIC code 4941).

3 - Impoundments used to collect seepage and run off at landfills (SIC code 4953).

The location of the municipal sites is depicted in Figure 4.3, and shows a higher concentration in the eastern half of the nation. The location of these sites is evidently tied to the population centers. The apparently higher concentration in Florida is deceptive since septic tank drainfields were included by this State in the inventory of municipal impoundments.

A breakdown by SIC codes is contained in Table 4.4, and shows that the majority of sites in this category are the sewage treatment plants and other domestic waste treatment facilities.

AGRICULTURAL SITES

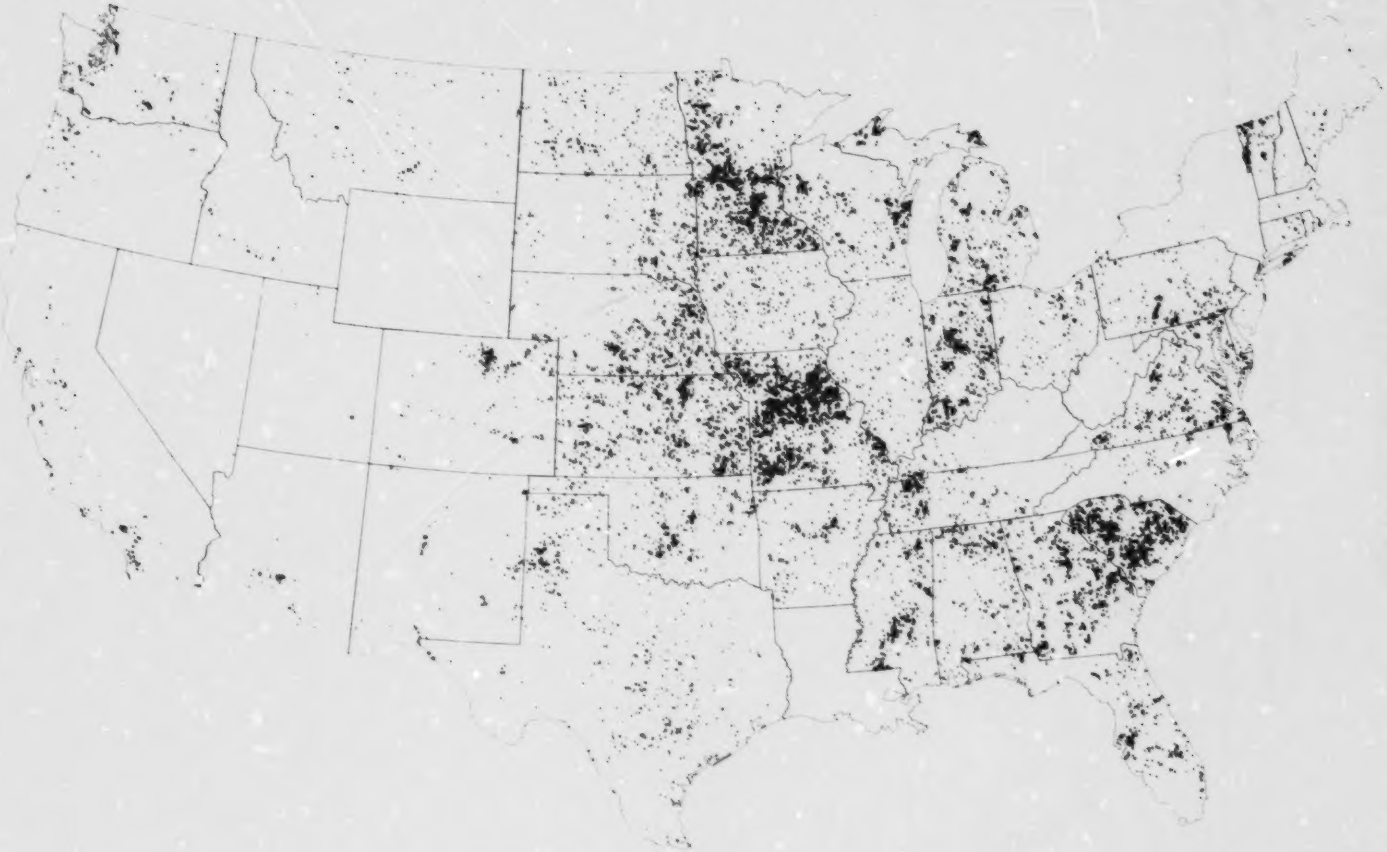


Figure 4.2

Note: Louisiana and Nevada did not
inventory agricultural sites

# SIC CODE BREAKDOWN
# OF
# AGRICULTURAL SITES

| SIC Code | Type Facility | Located Sites | Located Impoundments | Assessed Sites |
|---|---|---|---|---|
| 01 | Crop Production | 90 | 190 | 81 |
| 0211 | Cattle Feedlot | 1,599 | 2,974 | 413 |
| 0213 | Hogs | 2,528 | 3,492 | 1,062 |
| 021, 0212, 0214, 0291 | Livestock General | 4,402 | 5,333 | 2,049 |
| 0241 | Dairy Farms | 4,141 | 4,732 | 2,058 |
| 025 | Poultry Farms | 515 | 717 | 284 |
| 027 | Other Fur Bearing Animals | 215 | 336 | 132 |
| 029 | General farms | 1,112 | 1,208 | 504 |
| 0921 | Fish Hatcheries | 18 | 95 | 14 |

Table 4.3

MUNICIPAL SITES

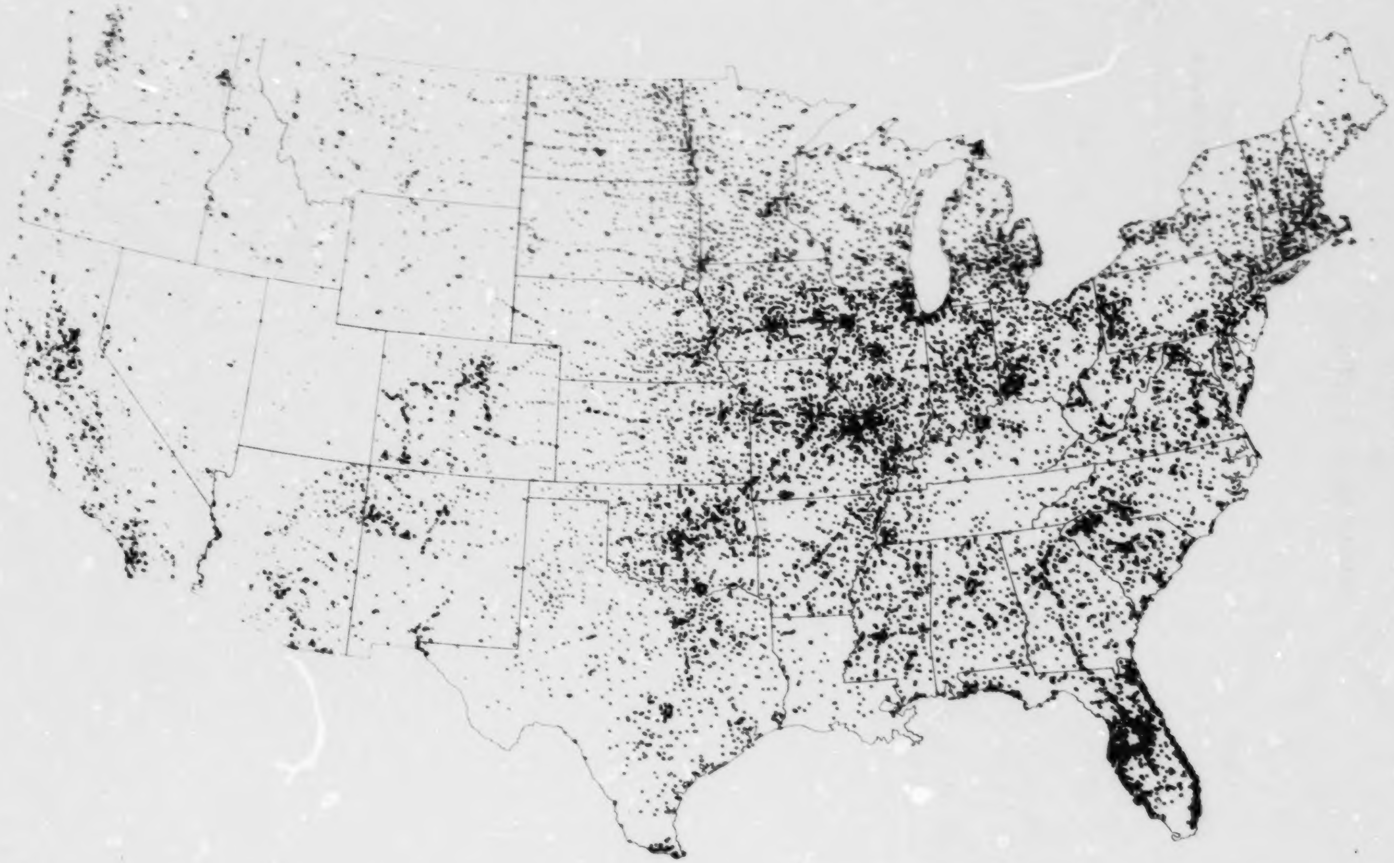


Figure 4.3

## SIC CODE BREAKDOWN
## OF
## MUNICIPAL SITES

| SIC Code | Type Facility | Located Sites | Located Impoundments | Assessed Sites |
|---|---|---|---|---|
| 4941 | Water Treatment Plant | 768 | 1,307 | 483 |
| | Sewage Treatment Plant | 17,467 | 32,856 | 9,740 |
| | Municipal Sanitary Landfill | 179 | 446 | 149 |

Table 4.4

The small number of sites in the sanitary landfill category is probably due to general lack of knowledge about these sites and may not be a true representation for this type of impoundment.

## Industrial Category

The industrial category includes all impoundments used in the processing, storage or disposal of industrial waste but excludes impoundments used for raw or processed material storage or in the manufacturing process. The location of the industrial sites is depicted in Figure 4.4, and shows a higher concentration in the eastern part of the nation and along the West Coast.

A breakdown by SIC codes is contained in Table 4.5 and shows that impoundments are widely used throughout industry. The most important users of impoundments are the food processing industry (2,087 sites and 4,960 impoundments) and the chemical industry (1,414 sites and 4,377 impoundments). Other industries accounting for more than 1,000 impoundments each are the petroleum refineries; power plants; paper and allied products; stone, clay and glass products; primary metals; and fabricated metals.

## Oil and Gas Category

The oil and gas category is comprised strictly of impoundments associated with oil and gas extraction, commonly known as brine pits. Two types of brine pits are found in the oil fields--disposal pits, which most States discourage except where they do not endanger ground water, and emergency pits, where generally the brine should not be held for more than 24 to 72 hours. Because they are used extensively and sometimes on a continuous basis, emergency pits, normally excluded from the SIA, were included by most States for this category. Well drilling mud pits were excluded and refinery wastes are included in the industrial category.

There are 24,527 oil and gas sites in the data base with a total of 64,951 impoundments, and 3,302 sites which have been assessed. A geographic breakdown of the sites is provided in Figure 4.5. Because of the high concentration of these brine pits in very localized areas, these sites are most often not representative of ownership or of single facilities as in the other categories. In Arkansas each oil field was considered a site; in the small fields, each impoundment was counted, but in the larger fields, the total count was extrapolated from the count in one portion of the field. New York assumed one impoundment per lease and used well coordinates for the impoundment location. Pennsylvania assumed one impoundment per well. In Texas the impoundments were grouped by oil field or by 5 minute quadrant. Coordinates for the center of the oil field or of the 5 minute quadrant were used as site coordinates. In New Mexico, all impoundments within a given

INDUSTRIAL SITES

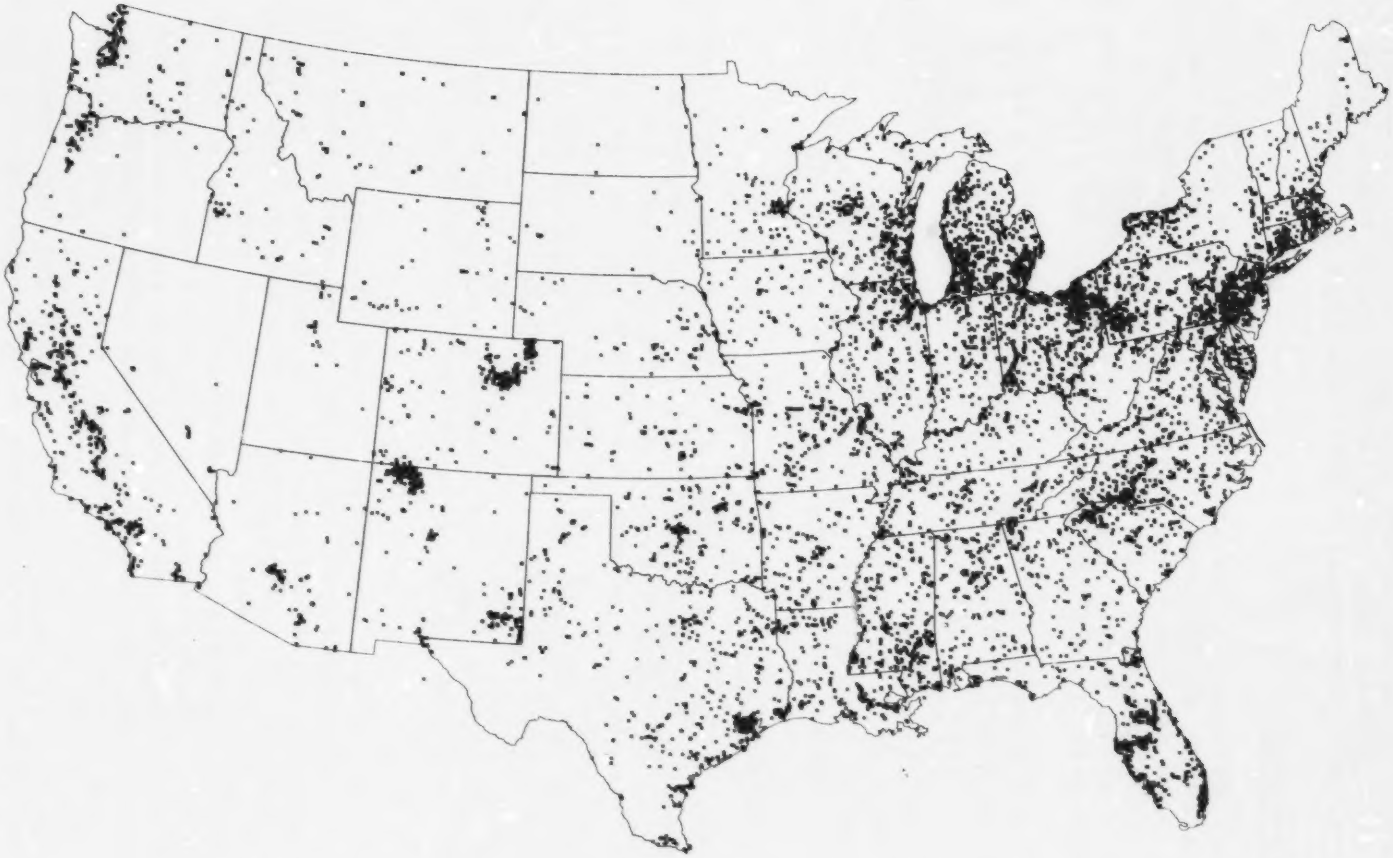


Figure 4.4

## INDUSTRIAL SITES

| SIC Code | Type Facility | Located Sites | Located Impoundments | Assessed Sites |
|---|---|---|---|---|
| 1389 | Oil Field Services | 266 | 764 | 97 |
| 07 | Agric. Services | 93 | 167 | 83 |
| 20 | Food | 2,087 | 4,960 | 1,608 |
| 21 | Tobacco | 6 | 11 | 5 |
| 22 | Textile Mills | 258 | 536 | 210 |
| 23 | Apparel | 10 | 13 | 10 |
| 24 | Lumber and wood | 348 | 781 | 294 |
| 25 | Furniture & Fixtures | 23 | 35 | 20 |
| 26 | Paper & Allied | 371 | 1,249 | 288 |
| 27 | Printing & Publishing | 18 | 24 | 15 |
| 28 | Chemical & Allied | 1,414 | 4,377 | 1,176 |
| 29 | Petroleum & Allied | 671 | 1,884 | 537 |
| 30 | Rubber & Misc. Plastics | 156 | 252 | 129 |
| 31 | Leather Products | 34 | 104 | 31 |
| 32 | Stone, Clay & Glass Products | 698 | 1,243 | 580 |
| 33 | Primary Metals | 574 | 1,380 | 444 |
| 34 | Fabricated Metals | 661 | 1,316 | 513 |
| 35 | Machinery | 174 | 294 | 141 |
| 36 | Electric & Electronic | 200 | 391 | 177 |
| 37 | Transportation Equip. | 217 | 487 | 152 |
| 38 | Instruments | 47 | 92 | 36 |
| 39 | Misc. Manufacturing | 235 | 359 | 120 |
| 40-47 | Transportation | 310 | 516 | 239 |
| 491 | Power Plants | 543 | 1,671 | 442 |
| 492 | Gas Production & Dist. | 240 | 543 | 63 |
| 493 | Combination Elec/Gas | 39 | 81 | 37 |
| 496 | Steam Suply | 17 | 35 | 14 |
| 4953 | Industrial Refuse Sites | 199 | 602 | 162 |
| 517 | Petroleum Bulk Terminal | 65 | 141 | 47 |
| 554 | Service Stations | 50 | 65 | 45 |
| 721 | Cleaning Establishments | 251 | 381 | 130 |
| 7542 | Car washes | 59 | 72 | 49 |

Table 4.5

OIL AND GAS SITES

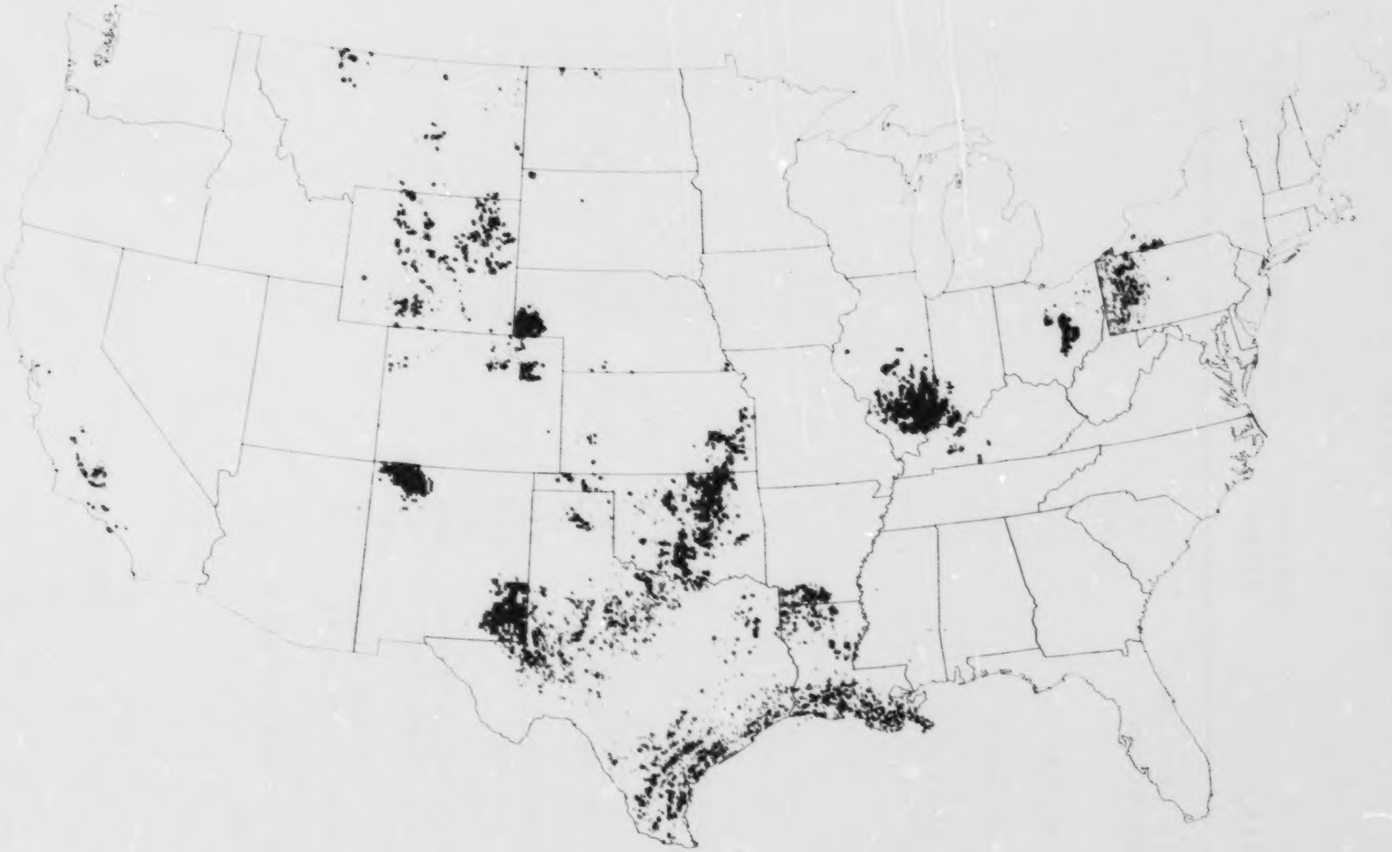


Figure 4.5

36 square mile township range were given the coordinate of the center of the range, which explains the regular pattern observed in that State.

## Mining Sites

The mining category includes impoundments associated with ore extraction and on site activities such as washing, crushing and sorting of ore, as well as treatment of mine wastewater. It does not include milling and processing wastes which are included in the industrial category.

The geographic distribution of mining sites is illustrated of Figure 4.6 and shows a higher concentration of sites in Pennsylvania, Ohio and West Virginia, associated mostly with coal mining. Some ore mining activity takes place in almost every State except Maine, New Hampshire, Rhode Island, Massachusetts and Delaware.

The type of mining activities going on in each State is illustrated in Figure 4.7. Table 4.6 which is a breakdown of mining sites by SIC code, shows that the majority of sites and impoundments are associated with bituminous coal and lignite mining.

As in the oil and gas category, the sites do not necessarily represent ownership or facilities. For example, in Ohio, the count includes "strip pits" grouped by 7.5 mn quadrangle with each quarter of the quadrangle counted as a site.

In Pennsylvania, the State assumed each deep mine permitted after January 1, 1966 had at least one impoundment located near the mine portal, and each surface mine permitted after January 1, 1972 was also assumed to have one impoundment. This method did not distinguish between active and abandoned sites.

## Abandoned Sites

Most States only recorded data on abandoned sites as they were found during the inventory of active sites. Some States did not inventory them at all; therefore, the data on abandoned sites are not complete and cannot be used to draw any conclusions on a nationwide basis since there are not enough facilities to provide a statistically valid data set.

The inventory of abandoned sites is presented in Appendix B.11. Abandoned sites account for 6 percent of all located sites in the data base. A distribution by category is shown in Figure 4.8 and is a reflection of the emphasis placed by the States on diverse categories rather than a true representation of the abandoned sites population. Most abandoned sites inventoried and most of the ones assessed fall in the industrial category.

MINING SITES

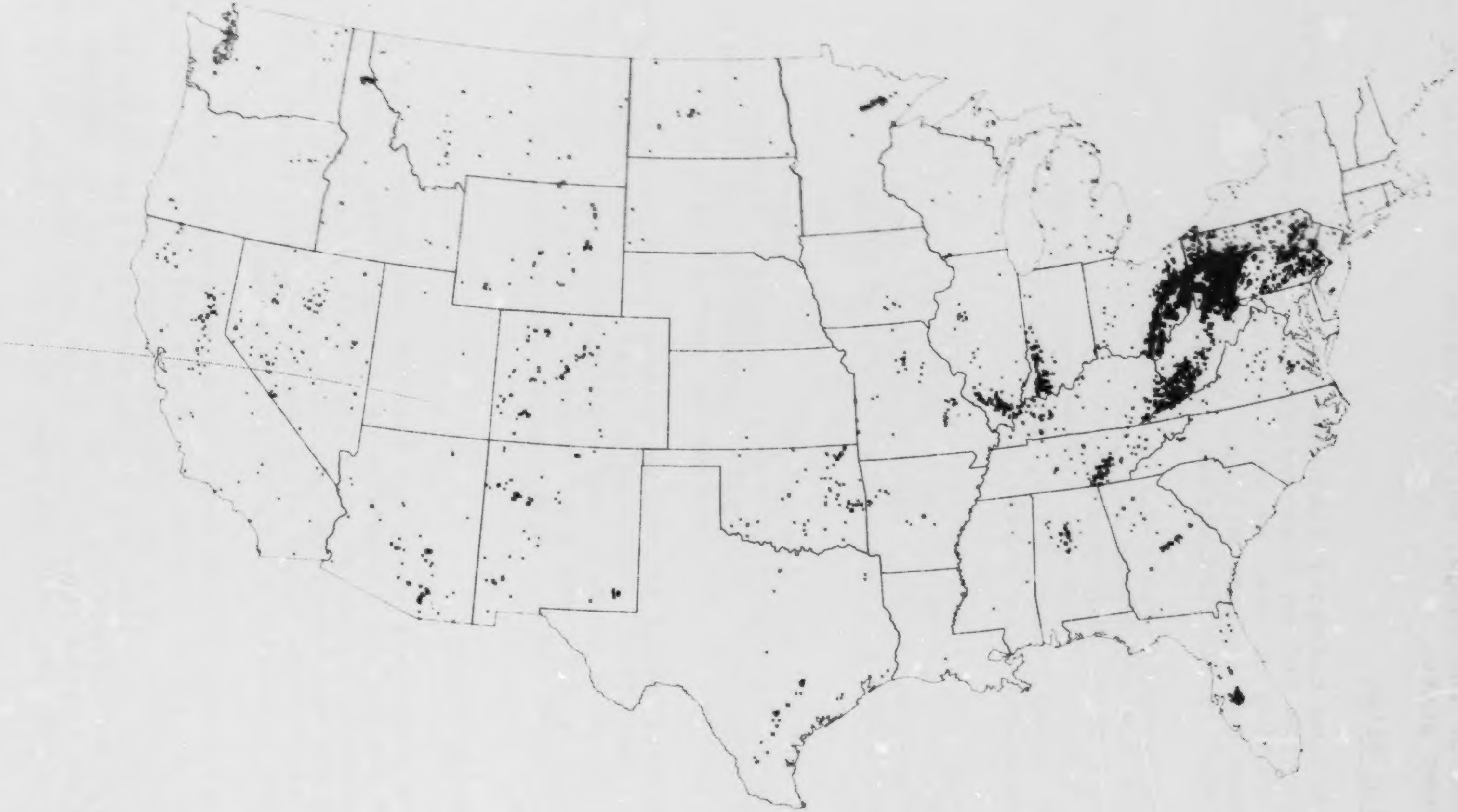


Figure 4.6

## TYPE OF MINING ACTIVITY

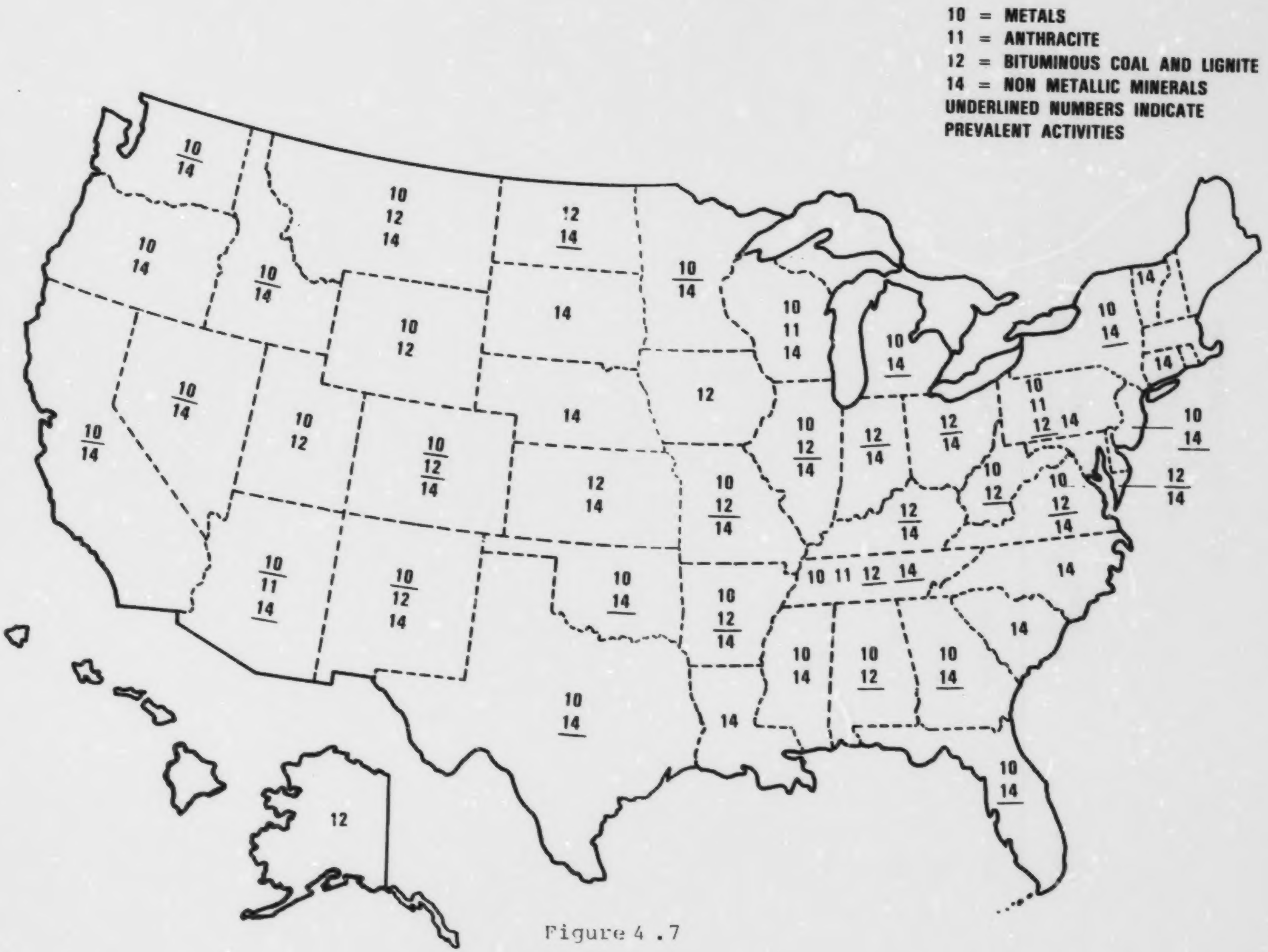

10 = METALS
11 = ANTHRACITE
12 = BITUMINOUS COAL AND LIGNITE
14 = NON METALLIC MINERALS
UNDERLINED NUMBERS INDICATE
PREVALENT ACTIVITIES
10 14
10 14
10 14
10 12 14
12 14
10 14
14
10 11 14
10 14
10 14
14
14
10 12
10 14
10 12
10 12 14
14
12
10 14
10 11 12 14
10 14
10 12 14
12 14
12 14
12 14
10 12
10 12 14
10 14
12 14
12 14
10 12 14
10 11 14
10 12 14
10 14
10 12 14
10 11 12 14
14
14
10 14
10 12
10 14
14
10 14
10 14
12

Figure 4 .7

# SIC CODE BREAKDOWN
# FOR
# MINING SITES

| SIC Code | Type Facility | Located Sites | Located Impoundments | Assessed Sites |
|---|---|---|---|---|
| 10 | Metals | 501 | 1,754 | 247 |
| 11 | Anthracite | 350 | 459 | 7 |
| 12 | Bituminous Coal and Lignite | 5,038 | 19,891 | 830 |
| 14 | Non-Metallic Minerals | 1,187 | 2,272 | 369 |

Table 4.6

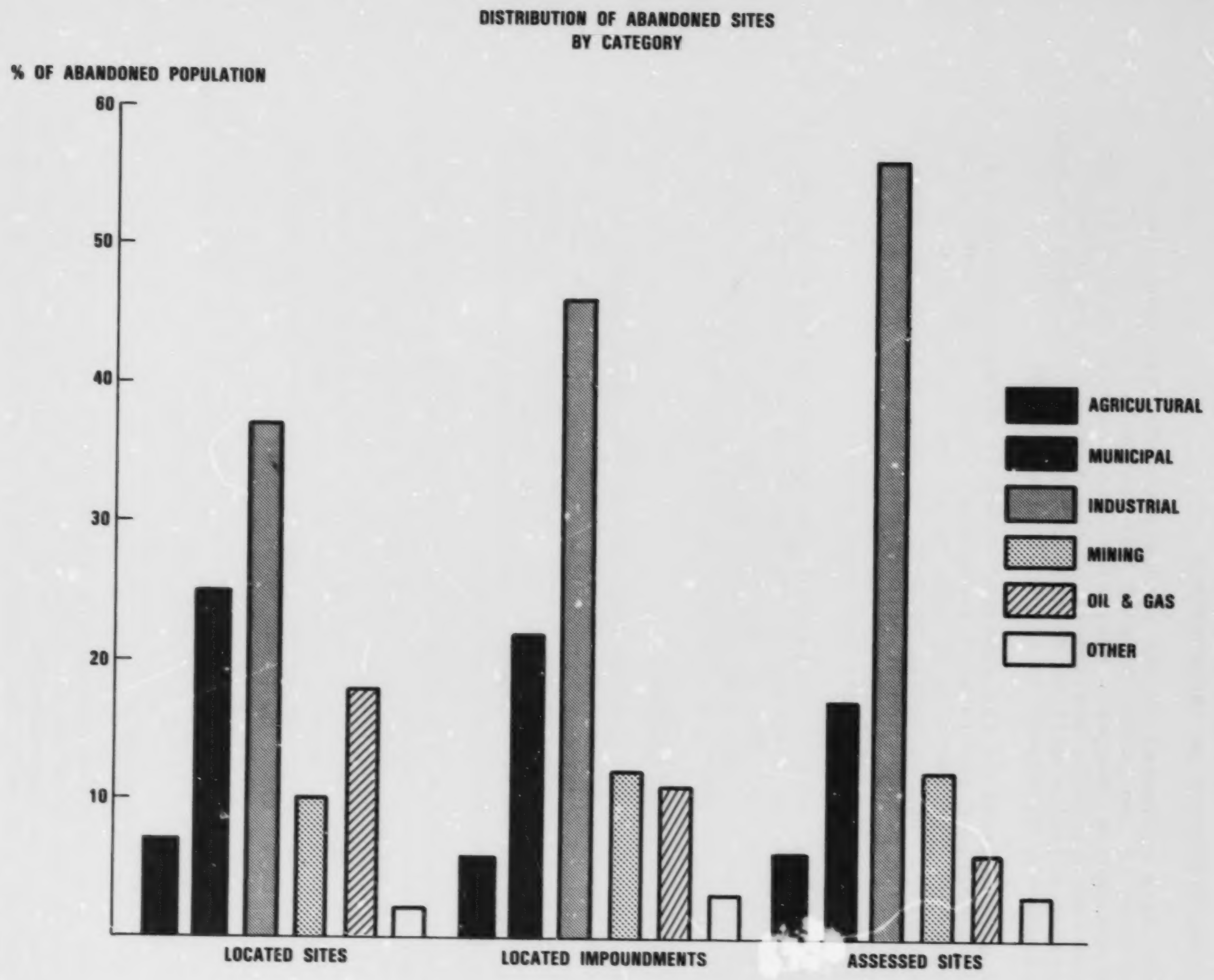

DISTRIBUTION OF ABANDONED SITES
BY CATEGORY
% OF ABANDONED POPULATION
60
50
40
30
20
10
LOCATED SITES
LOCATED IMPOUNDMENTS
ASSESSED SITES
AGRICULTURAL
MUNICIPAL
INDUSTRIAL
MINING
OIL & GAS
OTHER

Figure 4.8

## CHARACTERISTICS OF IMPOUNDMENTS

The data collected on the randomly chosen "assessed sites" consist of two parts, data on the characteristics of the impoundments (purpose, age, size, construction features) and the hydrogeologic assessment of the site. The impoundment characteristics will be discussed here, with the hydrogeologic assessment discussed in the following chapter.

A distribution of the assessed sites is shown in Figure 4.9. A majority of the located industrial sites (75 percent) were assessed, representing 41 percent of the impoundments in this category. Approximately half of the agricultural and municipal sites (45 percent and 56 percent respectively) were assessed, representing 37 percent of the agricultural impoundments and 38 percent of the municipal impoundments.

In contrast only 20 percent of the located mining sites and 13 percent of the located oil and gas sites were assessed. This represents 8 percent of the mining impoundments and 5 percent of the oil and gas impoundments, making detailed analysis of the data in these two categories less meaningful.

### Purpose of Impoundments

A summary of the primary purposes of the impoundments is contained in Table 4.7. In the municipal category, the primary purpose is treatment. Impoundments associated with water treatment plants are most often used for settling of sludges. At sewage treatment plants, the most common uses are settling of raw and treated sewage, and oxidation and stabilization of primary and secondary effluent.

Impoundments in the industrial category serve a multitude of purposes; 52 percent of the impoundments are used for treatment of the waste: settling, anaerobic or aerobic digestion, pH adjustment, equalization, polishing, etc. Fifty-five percent of the impoundments in the agricultural category are used for waste storage, usually prior to land application. In the mining category, the primary use is treatment which generally consists of settling prior to discharge into streams. In the oil and gas category the primary use (67 percent) is disposal; 29 percent of the oil and gas impoundments in the data base are storage, (i.e. emergency pits), and 4 percent are used for treatment prior to discharge, (usually oil skimming).

### Size of Impoundments

The size distribution of the impoundments in the various categories is shown in Table 4.8. In the agricultural category, most of the impoundments (87 percent) cover less than one acre in surface area with the largest reported agricultural impoundment 665 acres.

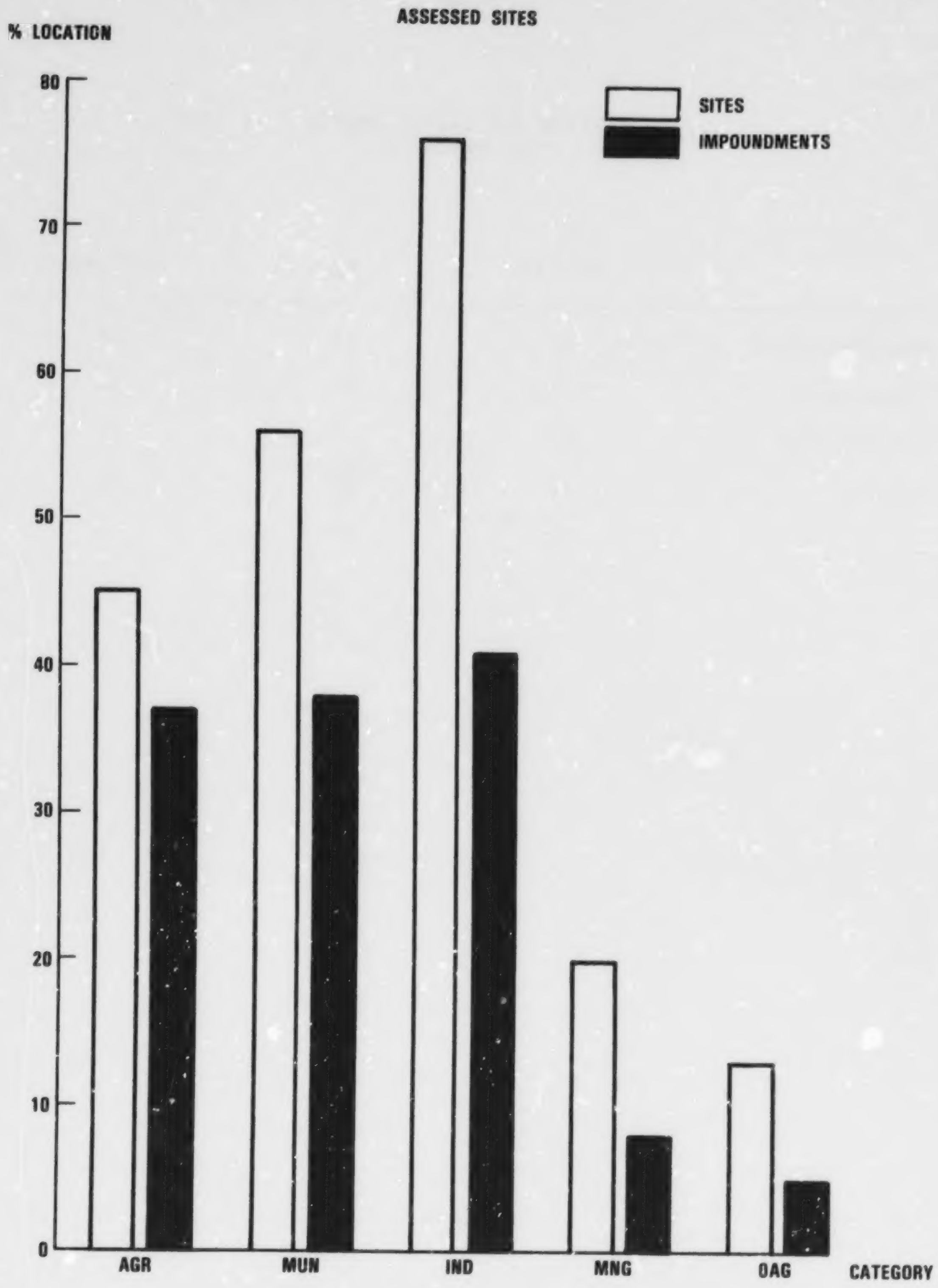

ASSESSED SITES
% LOCATION
80
70
60
50
40
30
20
10
0
SITES
IMPOUNDMENTS
AGR
MUN
IND
MNG
OAG
CATEGORY

Figure 4.9

## PURPOSE OF IMPOUNDMENTS
(By Percent)

| | Storage | Disposal | Treatment |
|---|---|---|---|
| Agricultural | 55 | 26 | 19 |
| Municipal | 5 | 31 | 64 |
| Industrial | 17 | 31 | 52 |
| Mining | 18 | 27 | 56 |
| Oil & Gas | 29 | 67 | 4 |

Table 4.7

# IMPOUNDMENT SIZE

(Acres)

| % Sites | <.1 | 0.1-<1 | 1-<5 | 5-<10 | 10-<100 | >100 |
|---|---|---|---|---|---|---|
| Agricultural | 20 | 67 | 10 | 1 | 2 | <1 |
| Municipal | 20 | 37 | 30 | 6 | 7 | <1 |
| Industrial | 29 | 40 | 20 | 5 | 5 | 1 |
| Mining-Metals | 10 | 26 | 22 | 6 | 29 | 7 |
| Mining-Coal & Lignite | 24 | 60 | 6 | 4 | 5 | 1 |
| Mining-Other Non-Metals | 5 | 21 | 22 | 11 | 21 | 20 |
| Oil & Gas | 46 | 29 | 23 | <1 | <1 | -- |

Table 4.8

In the municipal category, most of the impoundments are less than five acres (87 percent), with a slight predominance of impoundments in the 0.1 and 1 acre range. The larger municipal impoundments (largest reported is 850 acres) are usually oxidation ponds and sludge disposal lagoons.

The picture is similar in the industrial category where 89 percent of the impoundments are less than five acres. However, some 20 industrial impoundments have been reported which exceed 1,000 acres with the largest impoundment reported covering 5,300 acres. Most of these larger impoundments are located at power plants (cooling lakes), paper mills and copper refineries.

Because the practices included in the mining category vary widely in their use of impoundments, this category has been divided according to the SIC codes. Impoundments associated with coal mining are generally small; 84 percent are less than one acre.

They are larger in the other two categories. In the non-metal mining 52 percent of the impoundments are greater than five acres. Largest reported sizes are 299 acres in the coal mining category, 1,990 acres in the metals mining and 1,229 acres in the non-metal mining category.

Finally oil and gas impoundments are usually very small; 46 percent are less than 0.1 acres and 98 percent are less than five acres. The largest reported size is 79 acres.

## Characteristics of Impoundments - Liners

The data show that 16 percent of agricultural impoundments are lined. This number increases to 23 percent in the municipal category and 28 percent in the industrial category. For the mining and oil and gas categories, the percentage of lined impoundments is 17 percent and 10 percent respectively. It should be noted that for the purpose of the national report, impoundments which used soil amendments (such as bentonite mixed with native soil) or compacted soils to reach a low permeability were considered to be lined. In some instances, States did not count such as lined. A complete discussion of the liner categories is provided in Appendix A.

The distribution of lined impoundments varies from State to State as shown in Figures 4.10, 4.11 and 4.12 for the agricultural, municipal and industrial categories. Some States are consistently higher than the national average (Idaho, Nevada, Oregon, Illinois, Pennsylvania, and Kentucky). While this is indicative of a generally stronger water protection program, it is in some cases a result of the hydrogeologic settings or specific industrial practices in the State. In some States certain categories are given more emphasis than others. In addition

USE OF LINER IN THE
AGRICULTURAL CATEGORY

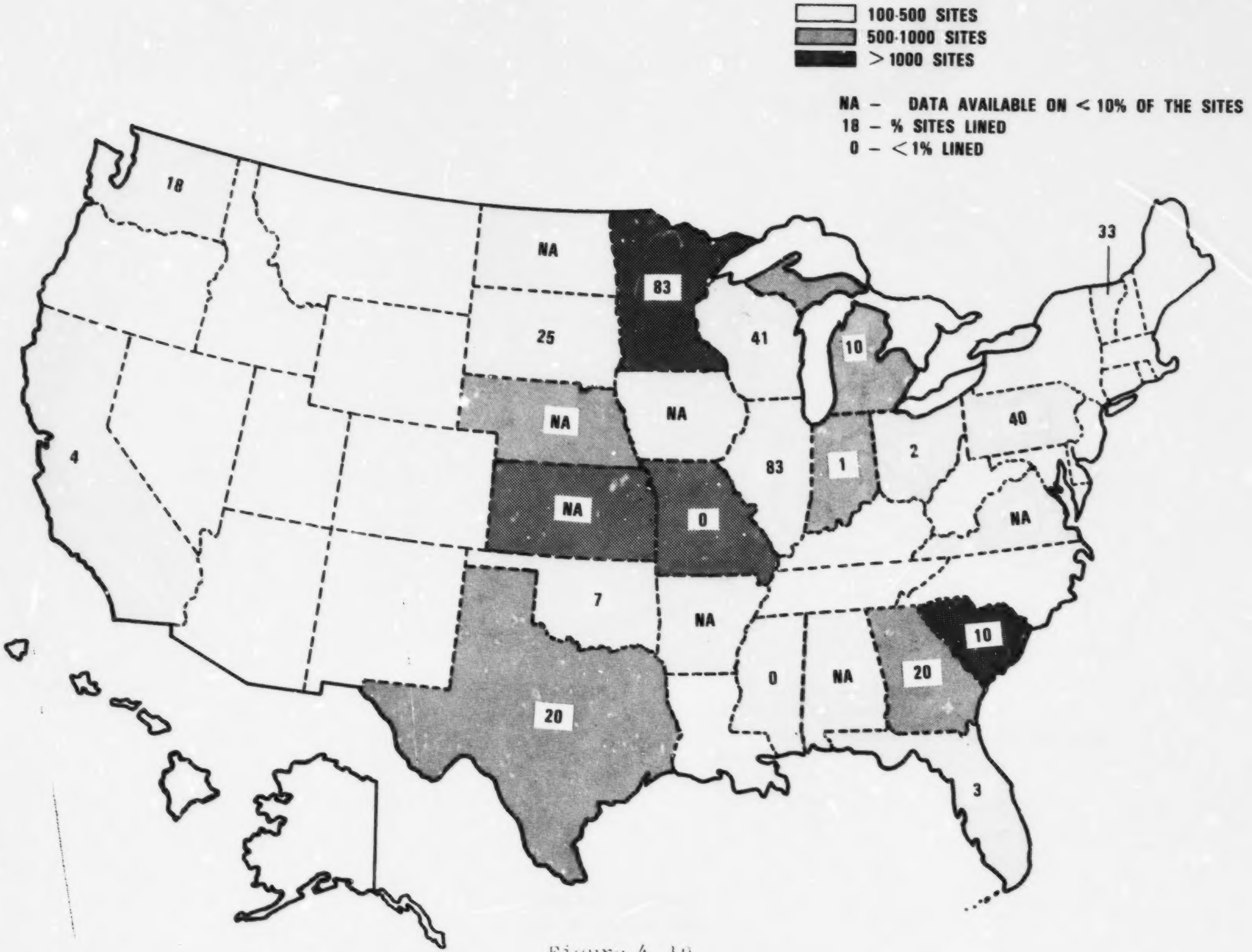
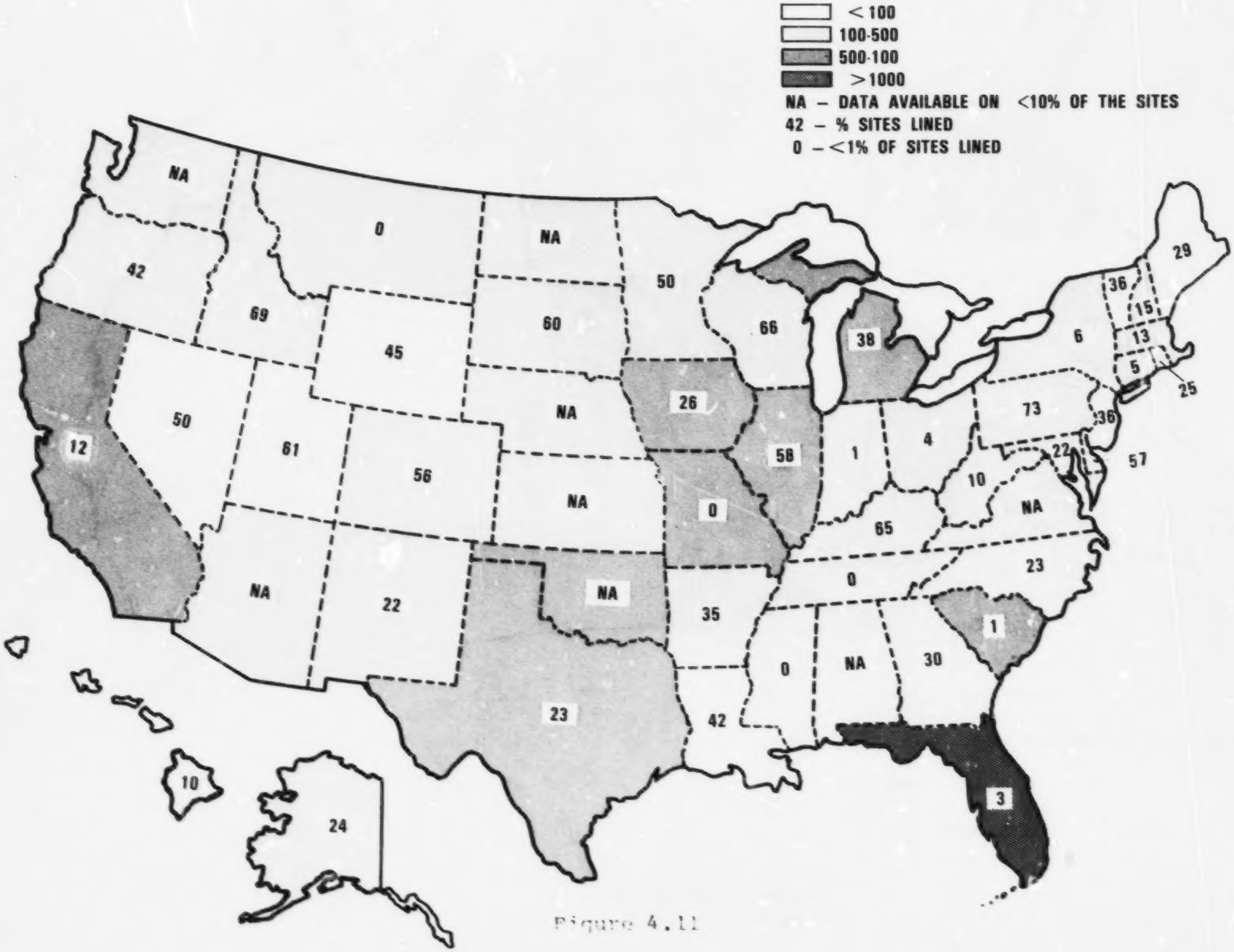

□ 100-500 SITES
▨ 500-1000 SITES
■ > 1000 SITES
NA – DATA AVAILABLE ON < 10% OF THE SITES
18 – % SITES LINED
0 – < 1% LINED
18
4
NA
25
83
NA
NA
NA
41
10
83
1
0
2
40
33
NA
7
NA
20
0
NA
20
10
3

Figure 4.10

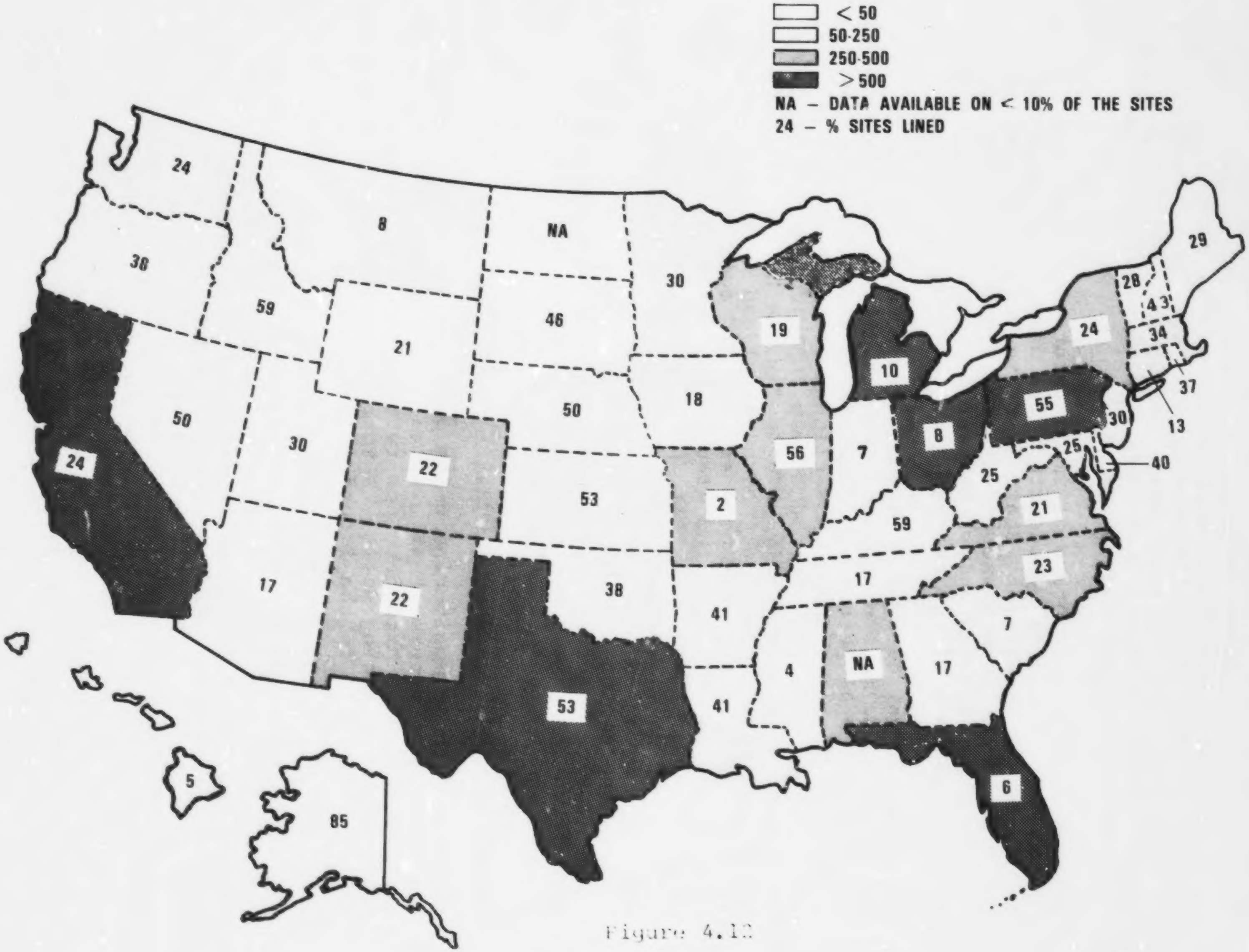
## USE OF LINER IN THE MUNICIPAL CATEGORY



< 100
100-500
500-100
>1000
NA – DATA AVAILABLE ON <10% OF THE SITES
42 – % SITES LINED
0 – <1% OF SITES LINED
NA
42
12
69
50
0
45
61
NA
56
22
NA
60
NA
NA
NA
23
50
26
0
35
42
66
58
38
1
4
0
65
0
NA
30
1
3
10
NA
23
73
22
36
57
6
36
15
13
5
25
29
10
24

Figure 4.11

USE OF LINER IN THE
INDUSTRIAL CATEGORY



< 50
50-250
250-500
> 500
NA – DATA AVAILABLE ON < 10% OF THE SITES
24 – % SITES LINED
24
38
8
NA
30
29
59
21
46
19
10
28
43
24
34
37
50
18
55
13
30
50
30
22
56
7
8
25
40
24
53
25
21
2
59
17
23
17
22
38
41
7
4
NA
17
41
53
5
6
85

Figure 4.12

to the States listed above, 50 percent or more of the industrial impoundments are lined in Texas, Nebraska, Kansas, and Alaska. In Minnesota 50 percent or more of the agricultural impoundments are lined, and more than 50 percent of municipal impoundments are lined in Wisconsin. In contrast, less than 10 percent of impoundments are lined in every category in Indiana, Ohio, South Carolina, Florida, Mississippi and Montana.

Because a small percentage of impoundments were assessed in the mining and oil and gas categories, the data in these categories do not lend themselves to State by State breakdowns. However, there was a sufficient amount of data to establish that in the oil and gas category, only 3 percent of the disposal pits are lined while 18 percent of the storage, i.e. emergency pits are.

In the municipal category, impoundments located at landfill sites are lined more often than the other types of impoundments (30 percent to 21 percent). Figure 4.13 shows that in the industrial category there is a slight relationship between the use of liners and the SIC codes (e.g., SIC codes that are associated with potentially hazardous waste have a slightly higher percentage of lined impoundments) and more particularly between the type of liner used and the SIC code. For example, in SIC code 36--electric and electronic, which includes battery manufacturing --more than half the liners are synthetic, while in SIC code 24--lumber and wood products--most liners are naturally occurring soil materials. There is also a relationship between the age of the impoundments and the use of liners (Table 4.9). Generally the younger impoundments are lined more often than the older ones, reflecting an increased awareness of the need to protect ground water.

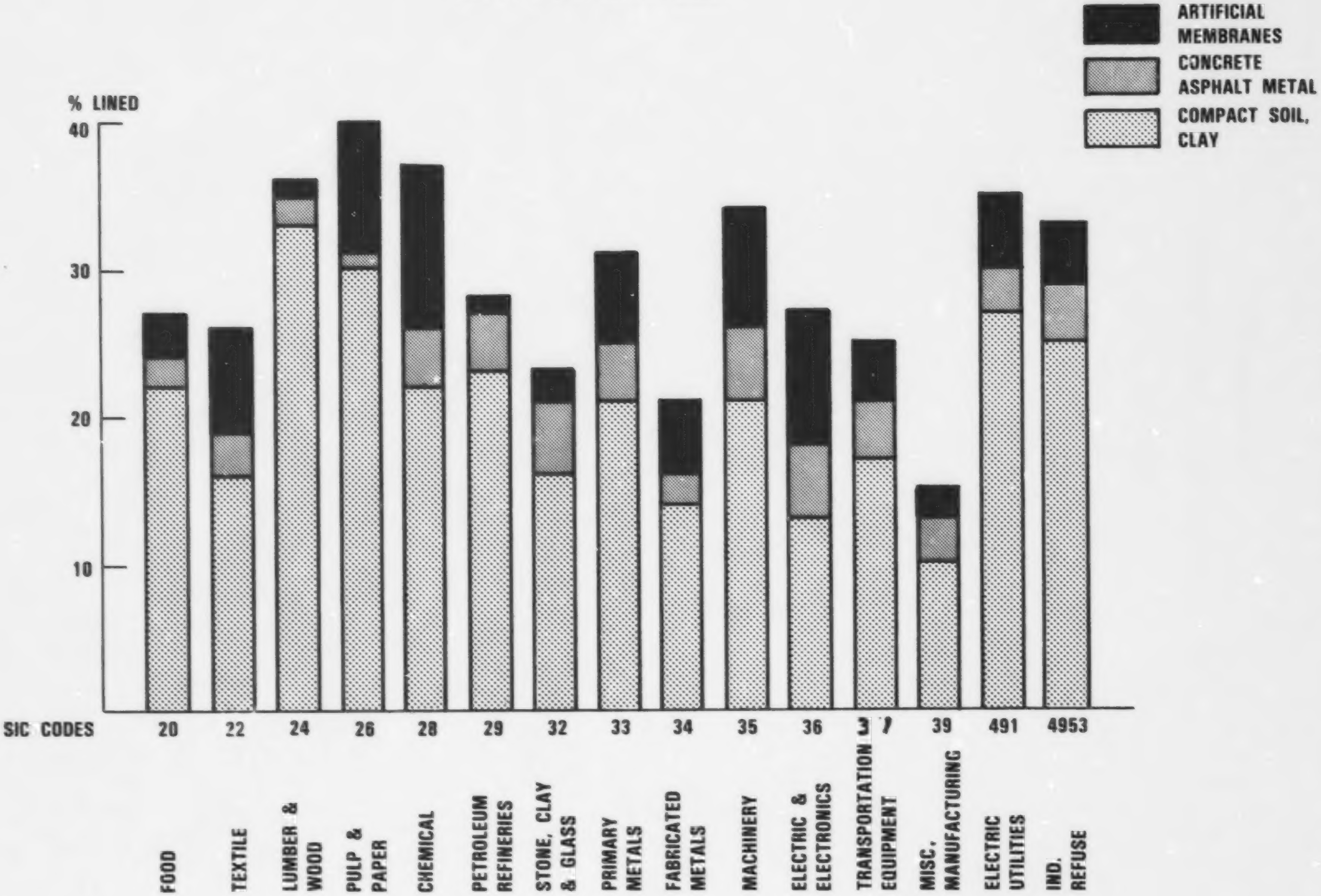
## Impoundment Surveillance - Monitoring Wells

When the data on monitoring wells were entered in the computer, the difference between "unknown" and "no monitoring wells" was lost and the only hard data now retrievable are the number of sites with monitoring wells. A total of 1,564 sites are monitored: 725 of these fall in the industrial category and 634 in the municipal category.

The distribution of known monitoring wells, by State, for the municipal and industrial categories is shown in Figure 4.14 and 4.15. Monitoring, like lining, is more prevalent in some States than others. Florida, Pennsylvania, Texas and California account for 44 percent of the sites known to be monitored in the industrial category, and Florida and California account for 64 percent of the sites known to be monitored in the municipal category. In the industrial category monitoring is more prevalent in certain SIC codes. The distribution of monitoring by SIC codes is shown in Figure 4.16. These data show that 32 percent of the industrial refuse sites and 20 percent of the sites in the

Figure 4.15

## INDUSTRIAL CATEGORY
## USE OF LINERS VS. SIC CODES



## COMPARISON OF
## INDUSTRIAL IMPOUNDMENTS
### Age vs. Liner

| AGE | % LINED |
|---|---|
| 1 - 5 | 36 |
| 6 - 10 | 30 |
| 11 - 15 | 23 |
| 16 - 20 | 25 |
| 21 - 30 | 17 |
| >30 | 18 |

Table 4.9

MONITORING WELLS
MUNICIPAL CATEGORY

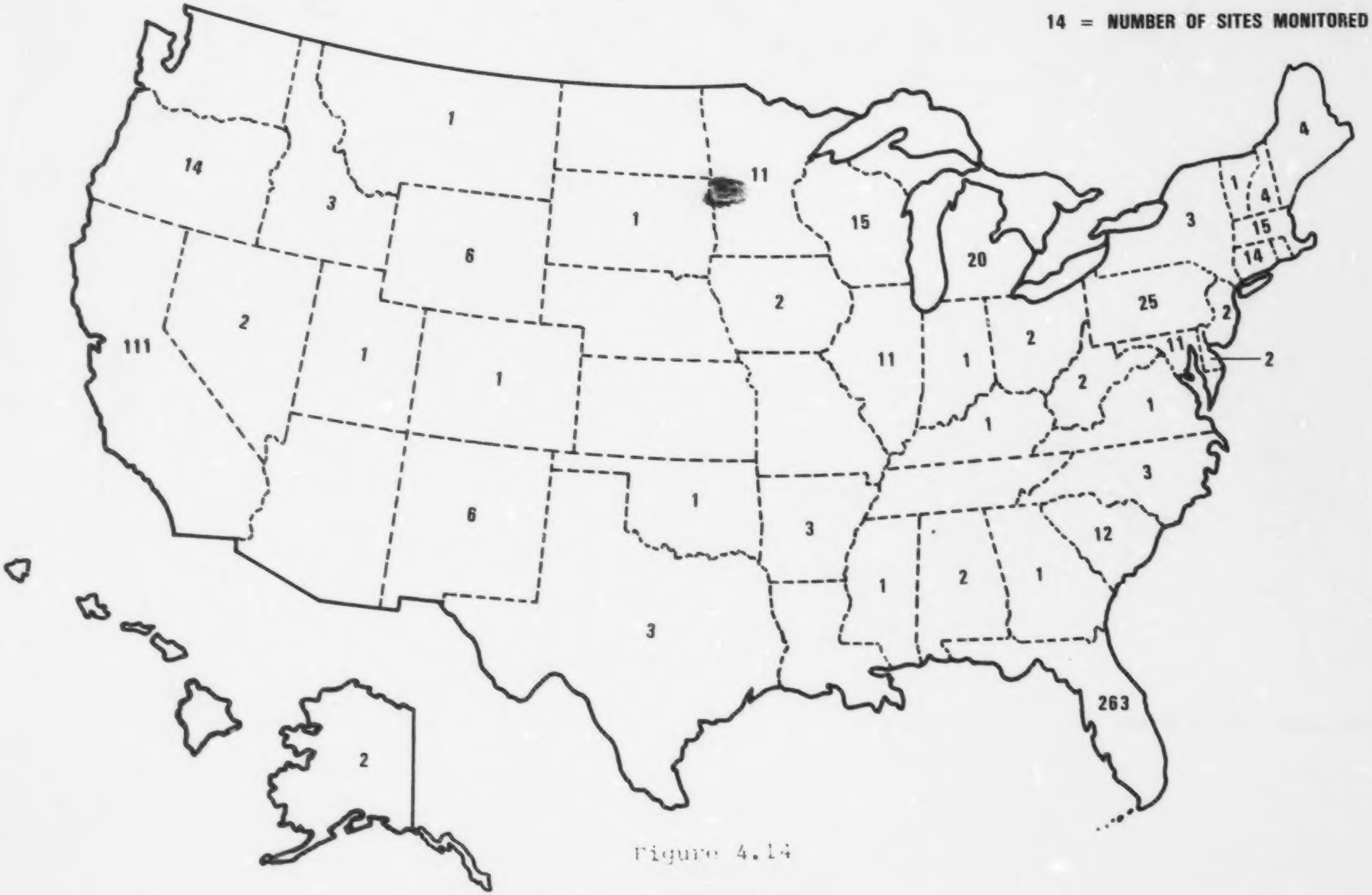

14 = NUMBER OF SITES MONITORED
14
111
3
2
1
1
6
1
1
6
1
11
1
2
3
3
15
11
20
1
1
1
2
2
1
25
11
2
2
1
3
12
263
3
1
4
15
14
4
2

Figure 4.14

## MONITORING WELLS
## INDUSTRIAL CATEGORY

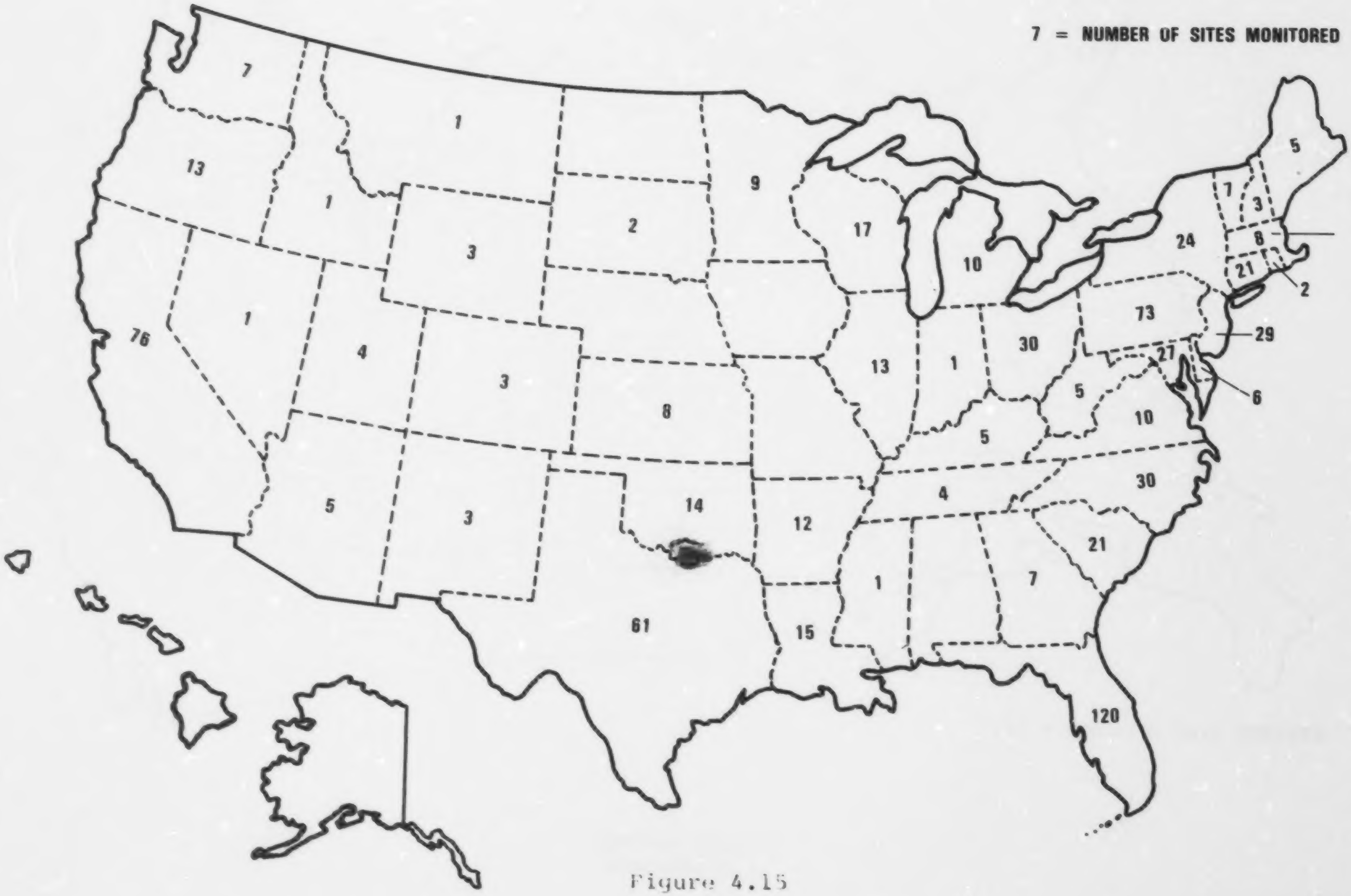

7 = NUMBER OF SITES MONITORED
7
13
76
1
1
1
4
5
3
3
3
1
2
8
14
61
9
17
13
12
15
10
1
4
1
5
30
5
10
30
21
7
120
73
27
29
6
24
7
3
8
21
2
5

Figure 4.15

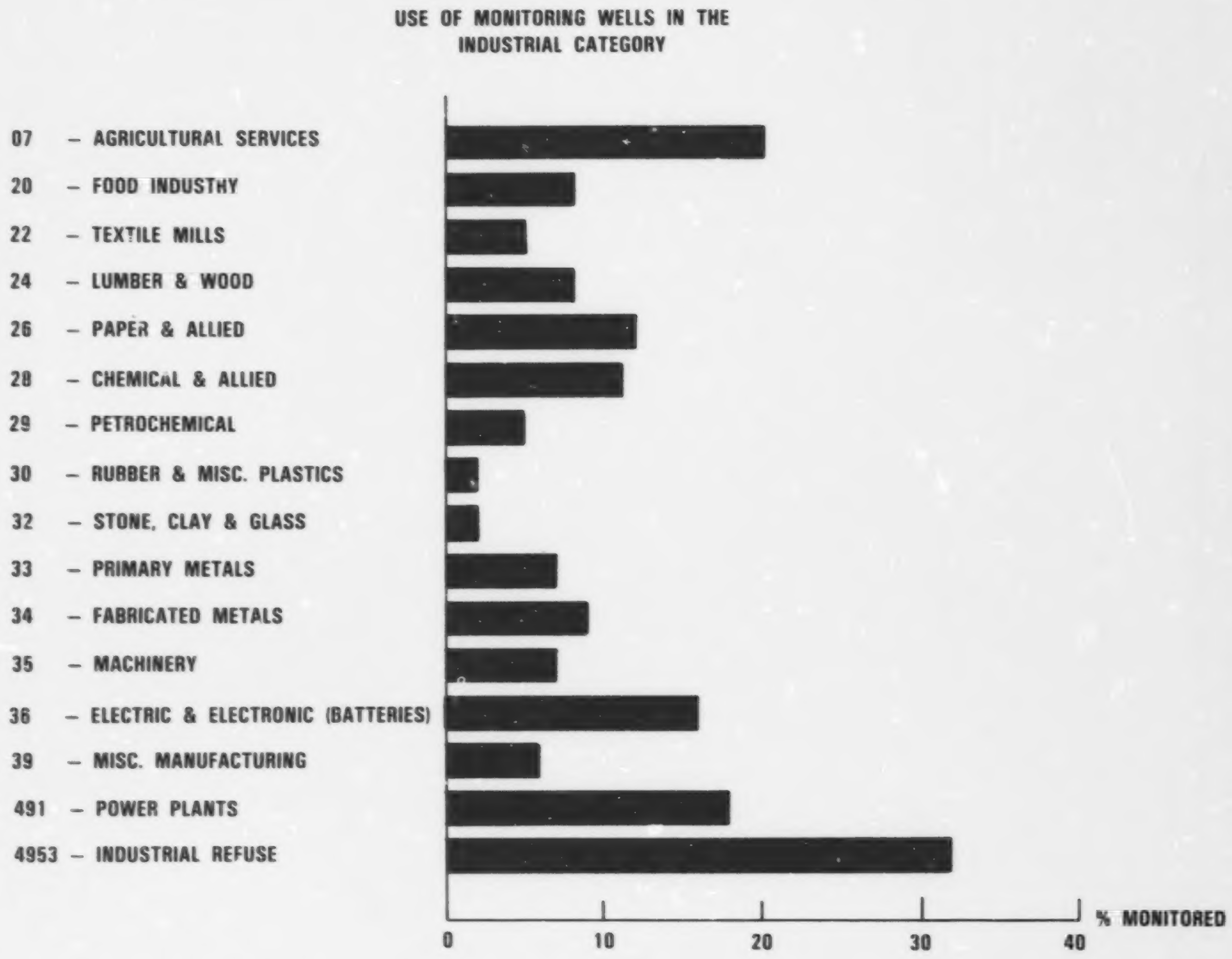

USE OF MONITORING WELLS IN THE INDUSTRIAL CATEGORY
07 – AGRICULTURAL SERVICES
20 – FOOD INDUSTRY
22 – TEXTILE MILLS
24 – LUMBER & WOOD
26 – PAPER & ALLIED
28 – CHEMICAL & ALLIED
29 – PETROCHEMICAL
30 – RUBBER & MISC. PLASTICS
32 – STONE, CLAY & GLASS
33 – PRIMARY METALS
34 – FABRICATED METALS
35 – MACHINERY
36 – ELECTRIC & ELECTRONIC (BATTERIES)
39 – MISC. MANUFACTURING
491 – POWER PLANTS
4953 – INDUSTRIAL REFUSE
0
10
20
30
40
% MONITORED

Figure 4.16

agricultural services category are being monitored; more than 10 percent of the sites are monitored in the Paper and Allied, Chemical and Allied and Electric and Electronic categories; and nearly 20 percent of the impoundments located at power plants are monitored.

# CHAPTER V

# ANALYSIS OF DATA

In this chapter, we will examine the results of the assessment and attempt to use the data to draw correlations that provide an insight on the potential impact of surface impoundments on ground water. Only the categories where the data can be considered valid on a nationwide basis will be used; these are data in the agricultural, municipal, industrial, mining and oil and gas categories. Excluded are the "abandoned" categories which are too incomplete, and the "other" category, which some States used to store data not directly related to the SIA, such as industrial septic systems and impoundments which were excluded by definition from the SIA. As in the preceding chapter, the numbers and percentages reflect the data base and are an approximation of the actual numbers.

## RESULTS OF THE ASSESSMENT

### Step 1, The Unsaturated Zone

Step 1 is intended as a measure of the ability of the unsaturated zone to impede or retard the downward movement of the waste contained in the impoundments. The score is based both on the thickness and lithology of the unsaturated zone.

A summary of the ratings for the unsaturated zone is shown in Table 5.1. This table shows a fairly even distribution of sites among the different types of earth materials, except for the very impermeable materials ($k = 10^{-7}$ cm/sec) where only 7 percent of the sites are located.

The numerical component of Step 1, which ranges from 1 to 9 can be used to divide the sites in three broad groups representing varying degrees of contamination potential.

Group I - A score of less than 3 represents sites located in thick and relatively impermeable unsaturated zones which would provide good protection to underlying aquifers.

Group II - A score of 3 to 6 represents sites where moderate protection to underlying aquifers is provided by a fairly impermeable or fairly thick unsaturated zone.

Group III - A score of greater than 6 indicates sites with a very thin or very permeable unsaturated zone affording little protection to underlying aquifers.

## STEP 1 - RATING OF THE UNSATURATED ZONE

| EARTH MATERIAL | Gravel, Medium to Coarse Sand<br>Cavernous or Fractured Limestone, Evaporites, Basalt Lava Fault Zones | | Fine to Very Fine Sand<br>Fractured Igneous and Metamorphic (Except Lava) Sandstone (Poorly Cemented) | | Sand with <15% clay, silt<br>Sandstone (Moderately Cemented) Fractured Shale | | Sand with >15% but ≤50% clay<br>Sandstone (Well Cemented) | | Clay with <50% Sand<br>Siltstone | | Clay<br>Unfractured Shale, Igneous and Metamorphic Rocks | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Permeability cm/sec | $>10^{-2}$ | | $10^{-4}$-$10^{-2}$ | | $10^{-5}$-$10^{-4}$ | | $>10^{-5}$ | | $>10^{-6}$ | | $>10^{-7}$ | |
| No. (%) Sites | 6,236 (20) | | 5,675 (18) | | 6,623(21) | | 4,720 (15) | | 6,148 (19) | | 2,093 (7) | |
| Thickness (m) | Score | No. | Score | No. | Score | No. | Score | No. | Score | No. | Score | No. |
| >30 | 9 | 1,017 | 6 | 843 | 4 | 775 | 2 | 544 | 0 | 693 | 0 | 384 |
| $>10 \leq 30$ | 9 | 892 | 7 | 760 | 5 | 1,053 | 3 | 959 | 1 | 1,635 | 0 | 422 |
| $>10 \leq 30$ | 9 | 1,398 | 8 | 833 | 6 | 2,039 | 4 | 2,118 | 2 | 2,239 | 0 | 648 |
| $>1 \leq 3$ | 9 | 1,386 | 9 | 1,002 | 7 | 1,864 | 5 | 778 | 3 | 1,319 | 1 | 385 |
| $>0 \leq 1$ | 9 | 1,543 | 9 | 2,237 | 9 | 892 | 9 | 321 | 9 | 262 | 9 | 254 |

Table 5.1

An analysis of Figure 5.1 shows that nearly 50 percent of the sites fall in Group III. This percentage is highest in the municipal and industrial categories where 56 percent and 50 percent of sites respectively are located in areas where they threaten underlying aquifers. Thirty percent of the sites fall in Group II. The percentage of agricultural sites found in this group is significantly higher (43 percent) than for sites in the other categories.

Finally, 22 percent of all sites are located in areas where the unsaturated zones afford good protection to underlying aquifers. This percentage is highest in the oil and gas category (47 percent) and lowest in the municipal category (16 percent).

## Step 2, The Saturated Zone

The Step 2 score is based on the saturated thickness and lithology, or the permeability of the saturated zone, and is a measure of the transmissivity of the aquifer. Table 5.2 shows that a majority of the sites (55 percent) are located over highly permeable aquifers, with only ten percent located over fairly impermeable formations ($k > 10^{-6}$ cm/sec). Using the same rationale as in Step 1, the sites can be divided in three groups:

Group I - A score of less than 3 indicates aquifers with very low transmissivity where contaminants would move slowly.

Group II - Sites where Step 2 = 3 are located over thin or moderately permeable aquifers.

Group III - A step 2 score greater than 3 indicates sites located in ares where thick and very permeable aquifers would allow a widely dispersed contaminant plume.

An analysis of Figure 5.2 shows that the data are definitely skewed towards Group III. Seventy-one percent of all sites fall in this group. The industrial category has the greatest percentage (78 percent), while the mining category has the lowest (47 percent).

Approximately 20 percent of all sites fall in Group II, with the mining category leading the ranks in this group (32 percent).

Only 11 percent of all sites fall in Group I. Mining and oil and gas sites appear more frequently in this group (21 percent and 18 percent respectively) than the other categories.

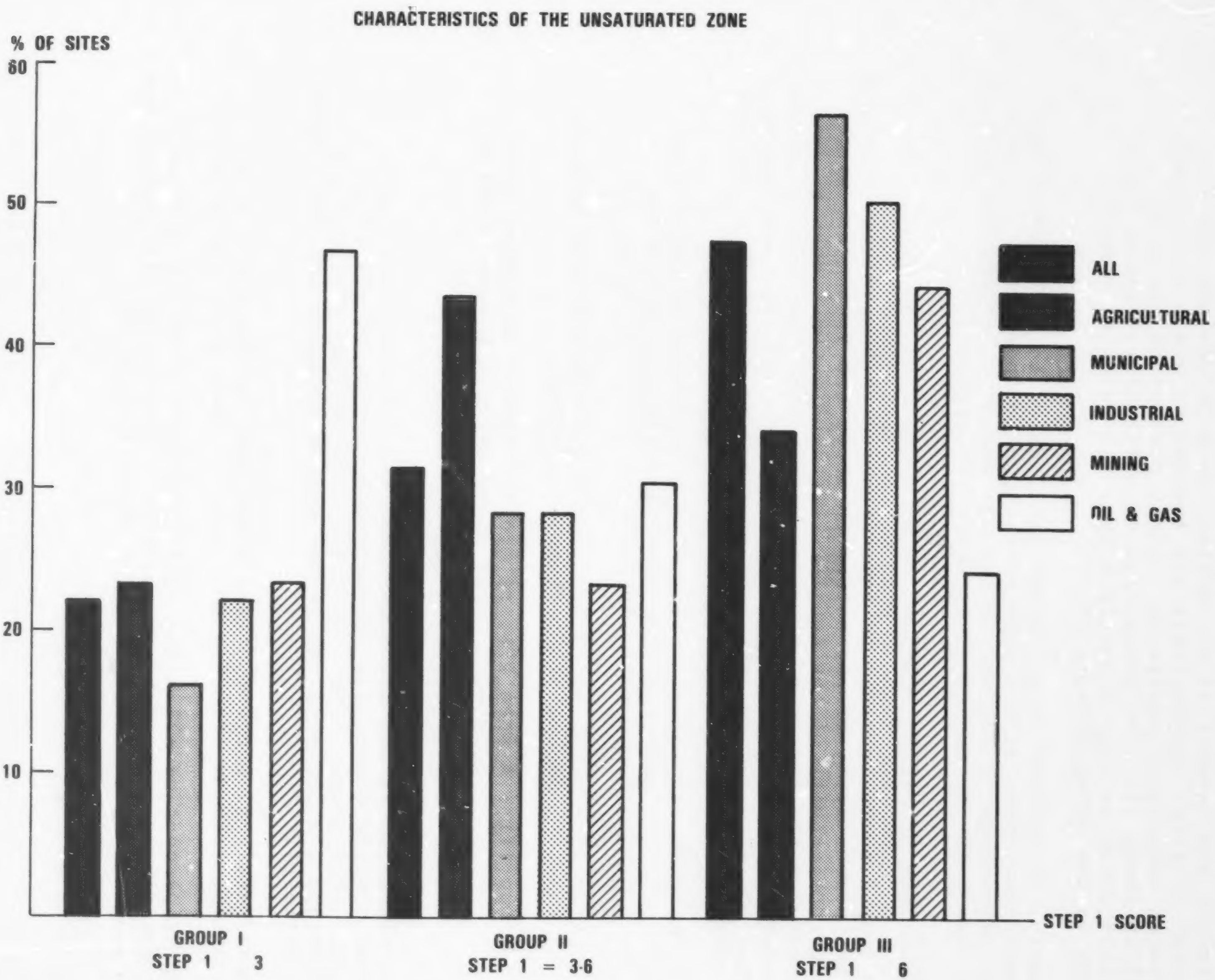

CHARACTERISTICS OF THE UNSATURATED ZONE
% OF SITES
60
50
40
30
20
10
ALL
AGRICULTURAL
MUNICIPAL
INDUSTRIAL
MINING
OIL & GAS
STEP 1 SCORE
GROUP I
STEP 1 3
GROUP II
STEP 1 = 3-6
GROUP III
STEP 1 6

Figure 5.1

## STEP 2 - RATING OF THE SATURATED ZONE

| EARTH MATERIAL | Gravel or sand<br>Cavernous or Fractured Rock, Poorly Cemented Sandstone, Fault Zones | Sand with >50% clay<br>Moderately Well Cemented Sandstone, Fractured Shale | Clay with ≥50% sand<br>Siltstone, Unfractured Shale and other Impervious Rock |
|---|---|---|---|
| Permeability (cm/sec) | $>10^{-4}$ | $10^{-4}$-$10^{-6}$ | $<10^{-6}$ |
| No. (%) Sites | 17,298 (55) | 11,069 (35) | 3,087 (10) |
| Thickness (m) | Score No. | Score No. | Score No. |
| >30 | 6 9,653 | 4 6,235 | 2 1,402 |
| 3-30 | 5 6,535 | 3 4,408 | 1 1,261 |
| ≤3 | 3 1,110 | 1 426 | 0 424 |

Table 5.2

# CHARACTERISTICS OF THE SATURATED ZONE

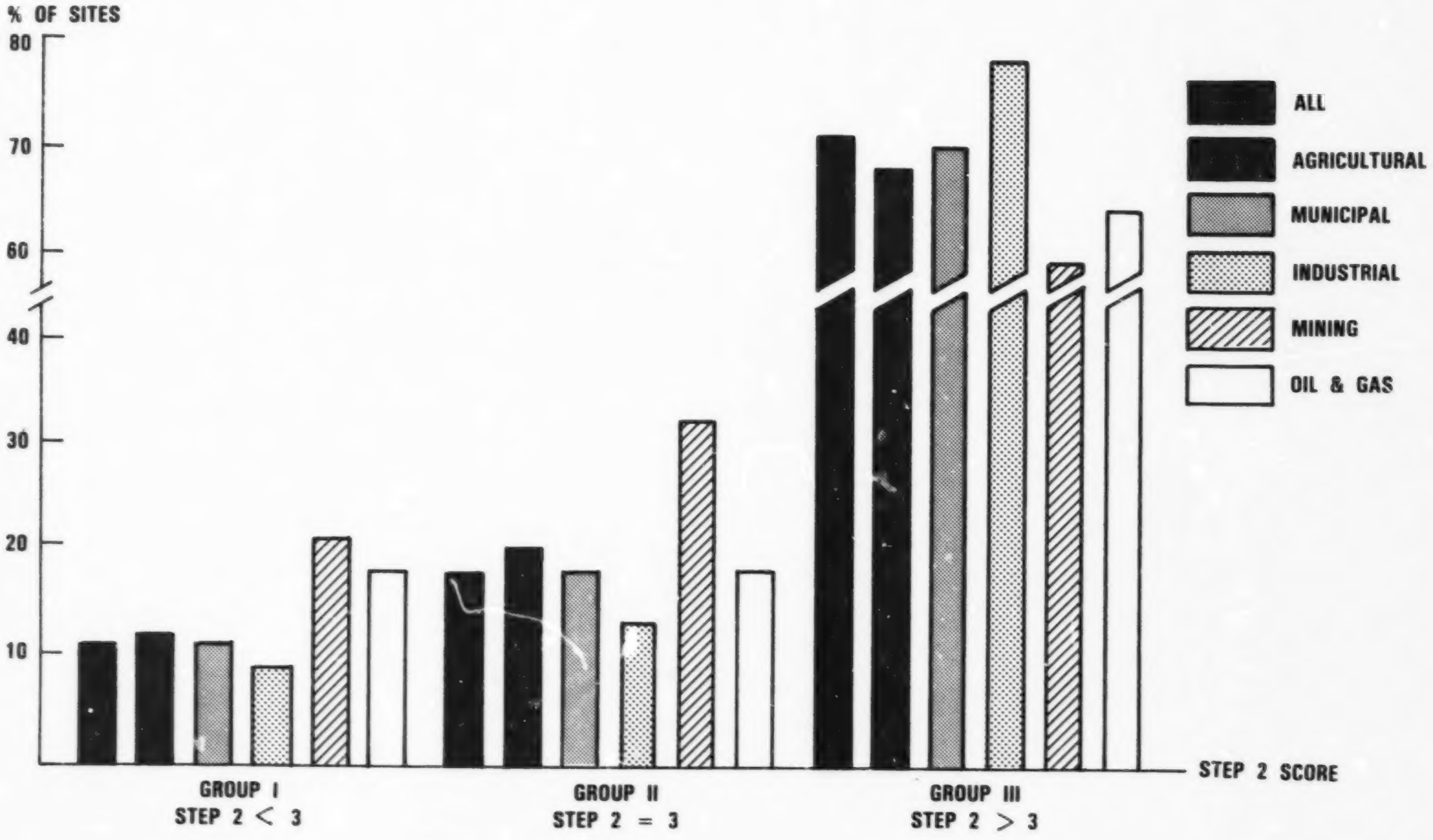


Figure 5.2

## Step 3, Ground Water Quality

Step 3 is a rating of Ground Water Quality based on current usage and total dissolved solids (TDS). Table 5.3 shows that almost 87 percent of the sites are located over aquifers currently used as a source of drinking water, while less than 2 percent are located in areas where there is no ground water or where it is extremely saline (>10,000 mg/l TDS). These proportions are constant throughout the different categories, as shown in Table 5.4, with the mining and oil and gas sites having a slightly lower percentage of sites located on drinking water aquifers (80 percent) and the industrial category having the highest percentage (89 percent).

## The Hydrogeologic Setting

Another way to look at the data provided in the first three steps of the assessment is to combine the scores to obtain a general picture of the hydrogeologic characteristics of the sites assessed. Two groups clearly emerge: sites with a low potential to contaminate an aquifer (Group I) and sites with a high potential to contaminate ground water (Group III). Between these two extremes are all other sites (Group II).

Group I - Low Endangerment Potential.

> This group is comprised of sites which fall in Group I for Steps I and II (i.e. are located in areas where the unsaturated zone is very thick or very impermeable and the aquifer has low transmissivity) and where the ground water is not currently used and of poor quality ($\geq$3,000 mg/l TDS) or where there is no ground water.

Group II - Moderate Endangerment Potential

> This group contains sites where a good aquifer is protected by a thick unsaturated zone, or sites where the ground water is not currently used but is of good quality: in other words, sites where potential endangerment is moderate, since seepage is somewhat mitigated by natural conditions.

Group III - High Endangerment Potential

> This group is comprised of sites which fall in Group III for Step I and II (i.e. located in areas where highly transmissive aquifers are poorly protected by thin or very permeable unsaturated zones) and where the ground water is currently used or of high quality 1,000 mg/l TDS).

## RATING OF THE GROUND WATER QUALITY

| Ground Water Quality TDS mg/l | No. of Sites (%) Located Over Aquifers Used As a Supply |
|---|---|
| ≤500 or current drinking water | 37,464 (86.7) |
| >500 - ≤1,000 | 1,629 ( 5.1) |
| >1,000 - ≤30,000 | 1,347 ( 4.2) |
| >3,000 - ≤10,000 | 629 ( 2.0) |
| >10,000 | 289 ( 0.9) |
| No ground water | 276 ( 0.9) |

Table 5.3

## GROUND WATER QUALITY RATINGS

## by CATEGORY

| Ground Water Quality (TDS mg/l) | AGR %Sites | MUN %Sites | IND %Sites | MNG %Sites | OAG %Sites |
|---|---|---|---|---|---|
| ≤500 or drinking water source | 88.1 | 88.4 | 88.7 | 80 | 80.1 |
| >500 - ≤1,000 | 3.6 | 4.4 | 5.8 | 7.9 | 7.5 |
| >1,000 - ≤3,000 | 2.2 | 4.2 | 3.0 | 8.5 | 10.3 |
| >3,000 - ≤10,000 | 4.0 | 1.9 | 1.2 | 2.4 | 0.6 |
| >10,000 | 0.8 | 1.1 | 1.2 | 0.5 | 0.1 |
| No ground water present | 1.6 | 0.5 | 0.7 | 1.7 | 1.1 |

Table 5.4

Figure 5.3 is a graph of the data grouped in this manner and shows that the majority of sites fall in Group II. Very few sites, 7 percent in all, can be discounted as presenting no threat to ground-water users based on their hydrogeologic characteristics. This proportion is slightly higher in the mining category (11 percent).

In the municipal and industrial categories, 41 percent and 39 percent of the sites respectively are in Group III, i.e. they have a higher potential to contaminate ground water, while only 8 percent or the oil and gas sites fall in that group.

Step 4, Waste Hazard Potential

In Step 4, the waste contained in the impoundments is assessed to determine its "hazard potential" and given a score of 1 to 9. Table 5.5 shows the results of step 4 in all but the oil and gas category where the uniform nature of the waste--brine--resulted in a score of 7 in 87 percent of the assessments.

The guidance for the SIA suggested a scoring range in the agricultural category of 1 - 2 for crops and 2 - 5 for livestock. Table 5.5 shows that the score is heavily skewed towards the upper end of the range, probably because in most instances, livestock operations are more frequently associated with impoundments. Pits used to dispose of pesticides or herbicides, and impoundments, such as dipping vats, account for the sites which scored higher than five in this category.

In the municipal category, the suggested range for rating the waste hazard was 2 to 5 and the scores are fairly evenly distributed within that range. The sites scoring higher than 5 are probably associated with facilities where there is a heavy contribution of industrial waste.

Scores in the industrial category are fairly evenly distributed between 2 and 9, while in the mining category, most sites fall within the range of 2 to 7, with the emphasis towards the upper end of the scale.

Figure 5.4 shows that overall, 25 percent of the sites contain wastes which, while they can degrade water quality, appeared at the low end of the rating (score <4), while 15 percent contain waste which may be considered hazardous (score >7). Mining and industrial sites are predominant in the potentially hazardous category. The reason that mining wastes rank so high is not so much because of their toxicity but because of the high volumes involved. Since volume was a consideration in the waste hazard rating, mining sites received a high score.

HYDROGEOLOGIC CHARACTERISTICS
OF ASSESSED SITES

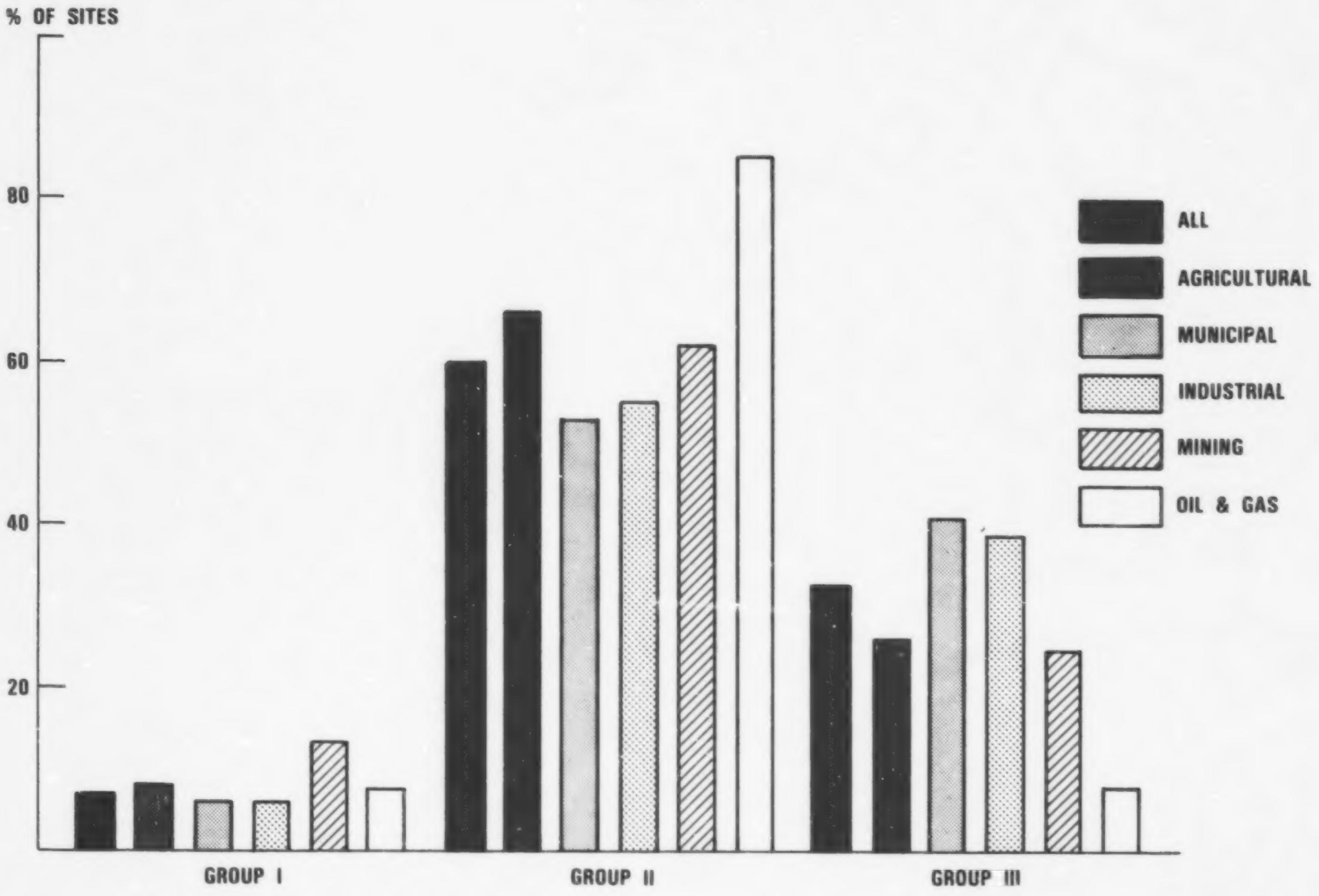


Figure 5.3

# WASTE HAZARD POTENTIAL RATING

| Score | AGR | MNN | IND | MNG |
|---|---|---|---|---|
| 1 | 14 | 24 | 19 | 3 |
| 2 | 97 | 1,236 | 913 | 210 |
| 3 | 301 | 2,997 | 1,251 | 51 |
| 4 | 2,333 | 2,278 | 993 | 55 |
| 5 | 3,625 | 3,035 | 935 | 112 |
| 6 | 15 | 809 | 1,277 | 348 |
| 7 | 28 | 163 | 927 | 659 |
| 8 | 10 | 230 | 1,141 | 8 |
| 9 | 91 | 38 | 767 | 11 |

Table 5.5

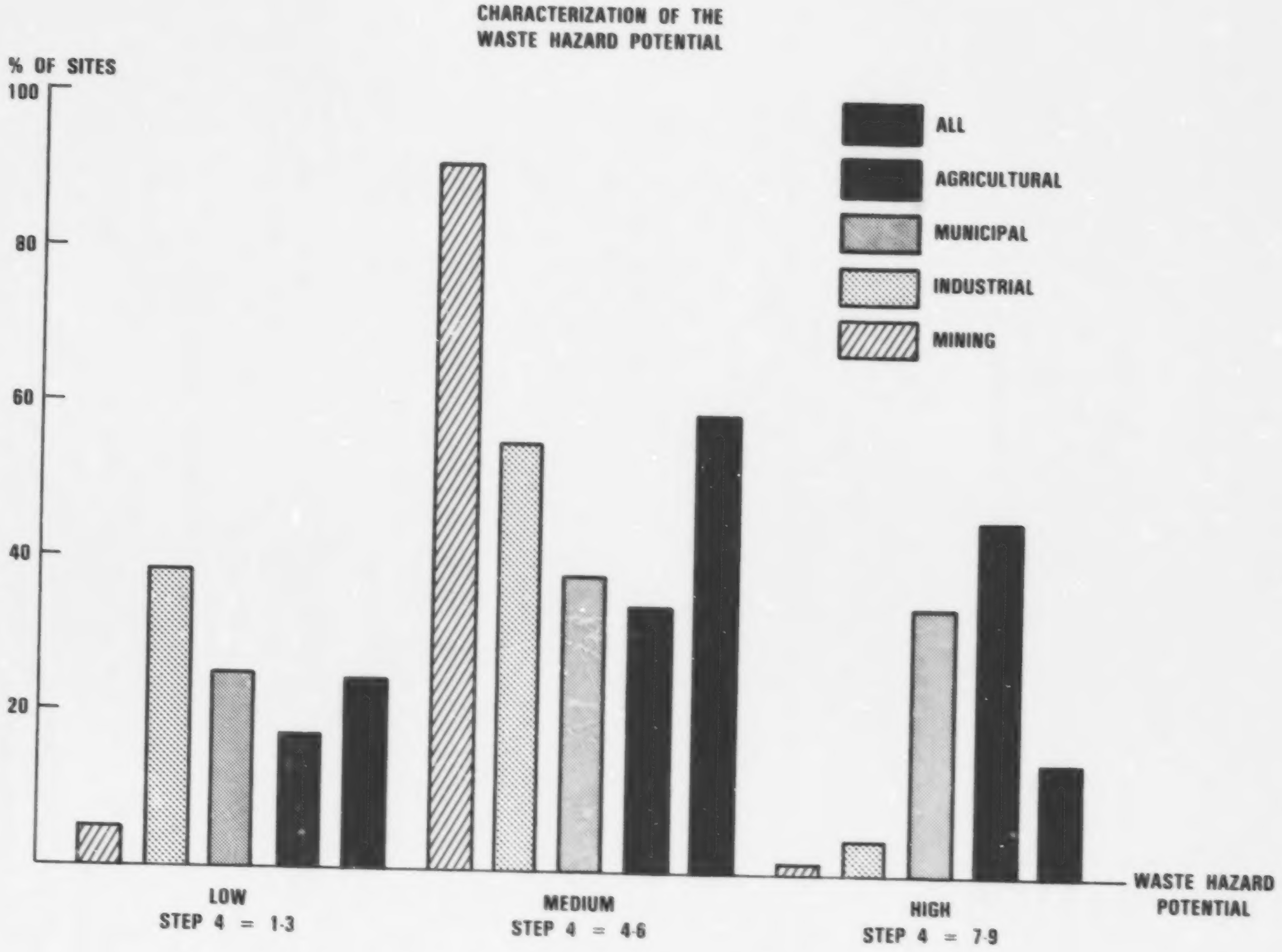

CHARACTERIZATION OF THE
WASTE HAZARD POTENTIAL
% OF SITES
100
80
60
40
20
ALL
AGRICULTURAL
MUNICIPAL
INDUSTRIAL
MINING
LOW
STEP 4 = 1-3
MEDIUM
STEP 4 = 4-6
HIGH
STEP 4 = 7-9
WASTE HAZARD
POTENTIAL

Figure 5.4

The waste rating was based either on the SIC code of the facility or the nature of the waste. In the agricultural, municipal, mining and oil and gas categories, the nature of the waste is almost always clearly related to the SIC code and little variation except for degree of treatment can be expected within each SIC code.

Within the industrial category, there is greater variation in the waste streams for industrial sites, and the scores may misrepresent the true hazard potential when SIC codes are used to determine the rating. However, in 44 percent of the cases, the assessments are based on the waste identification, not the SIC code, and thus any potential for misrepresentation is somewhat mitigated.

Figure 5.5 shows how the various SIC codes differ in degree of hazard. In the chemical and petroleum refining categories, as well as fabricated metals manufacturers and industrial refuse sites, more than 60 percent of the sites contain potentially hazardous waste. At the other end of the spectrum are the food processors and stone, clay, glass and concrete products industry, where less than 10 percent of the waste is hazardous.

### Step 5

The step 5 score is the sum of the scores obtained in steps 1, 2, 3 and 4. Figure 5.6 shows the range, mean and mode of step 5 for each category. The step 5 score is most meaningful at each end of the range. If a site ranks lower than 14, it is probably not posing a threat to ground water, while a site that ranks higher than 26 must contain potentially hazardous waste and be located above a vulnerable aquifer. Between these two extremes, the scores can represent a variety of conditions and they should not be considered alone. For example, a score of 23 can represent an impoundment located on a very vulnerable aquifer but containing fairly innocuous waste (Step 1 = 9, Step 2 = 6, Step 3 = 6, Step 4 = 2) or an impoundment containing potentially hazardous waste (Step 4 = 7) located on a good aquifer (Step 2 = 6, Step 3 = 5) protected by less than 3 meters of clayey sand (Step 1 = 5D). For this reason, the step 5 score is most meaningful when the individual steps are considered in evaluating the total score.

### Step 6, Potential Endangerment to Human Health

Step 6 looks at the potential for a site to endanger human health by assessing its proximity, and therefore its potential impact, on a water supply.

By using 7.5' topographic maps or other available information, a determination was made of:

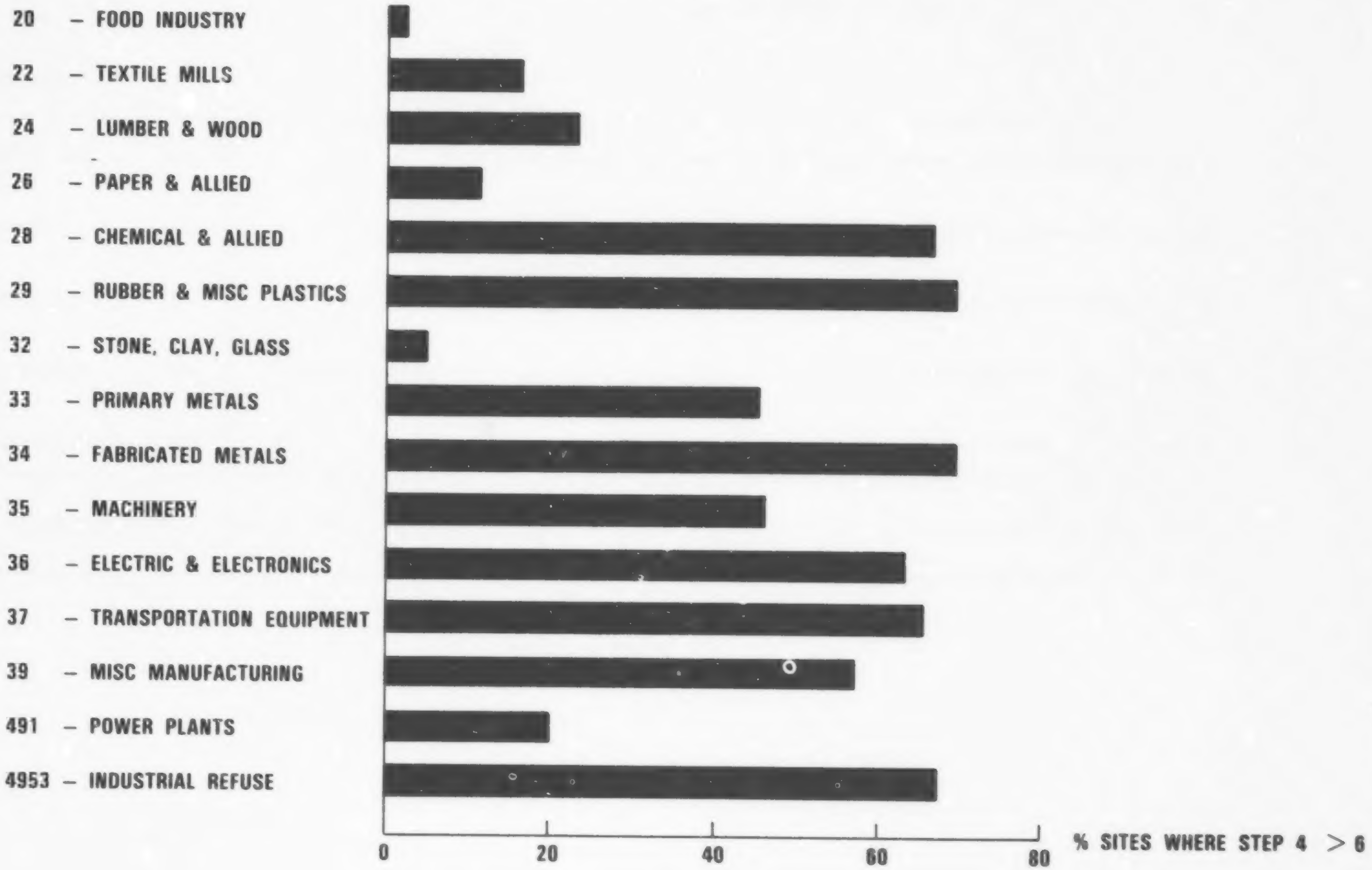

INDUSTRIAL CATEGORY
SITE WITH HIGH WASTE HAZARD POTENTIAL

Figure 5.5

STEP 5 SCORE

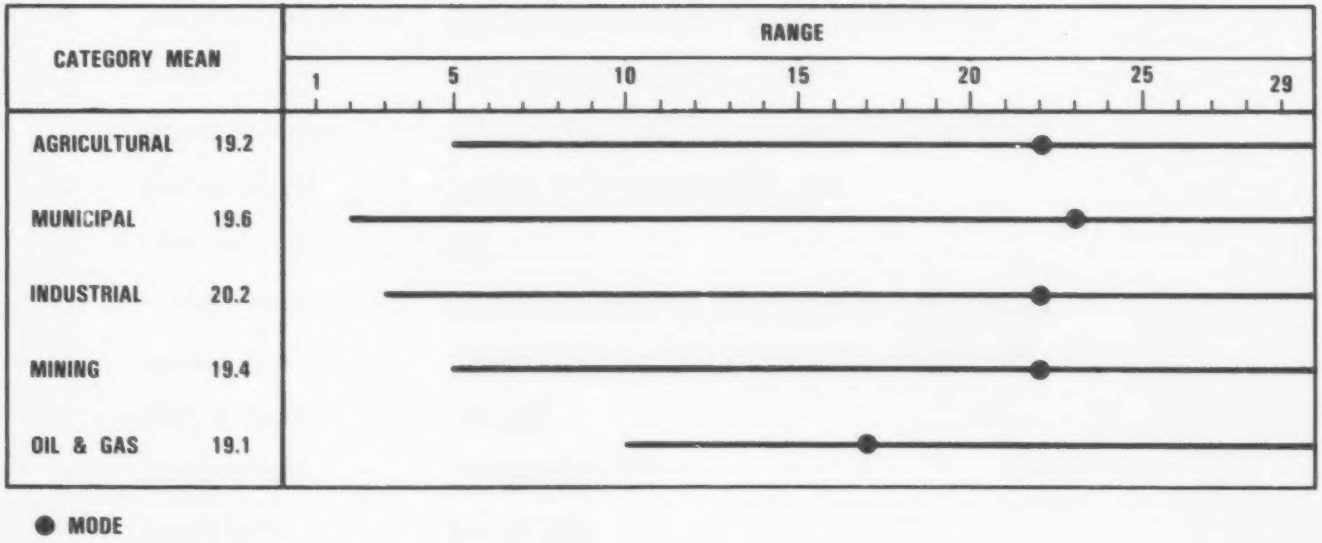


Figure 5.6

(1) the anticipated flow direction of seepage from the site

(2) whether a potential plume of contamination would first intersect a water well supply or a surface water supply, and the distance of this water supply from the site.

Where no hard data were available, the States were to assume that any stream other than intermittent was a potential water supply and that any well shown on the topographic maps was a drinking water well. Furthermore, in rural areas any house was assumed to use a water well.

Table 5.6 shows that 26 percent of all sites assessed would have a potential impact, primarily on ground-water supplies, while in the majority of cases (60 percent), the impact of any seepage would affect primarily a surface water supply via ground-water discharge into that surface water.

These percentages are fairly constant in each category, as illustrated in Table 5.7, with the proportion of surface water supply to ground-water supply slightly higher in the mining and oil and gas category, and lowest in the industrial category. These proportions vary from State to State as illustrated in Figure 5.7 which shows areas of the country where surface water supply would be the primary affected entity (>60 percent of the site potentially affect a surface water supplier) and those areas in which ground water supplies would be the primary affected entity (>60 percent of the sites potentially affect a ground water supply).

As discussed above, sites in the "Group III" hydrogeologic setting are the ones most likely to contaminate ground water. Table 5.8 shows that 31 percent of these sites are likely to impact primarily a ground-water supply while 57 percent are likely to impact a surface water supply. The proportion in each category is similar to those of the population as a whole, except in the municipal and industrial categories where the ratio of ground water supply to surface water supply is slightly higher for the "Group III" sites.

## GROUND-WATER PROTECTION

### The Use of Liners

The determining factors in whether or not a site is lined should be the nature of the unsaturated zone (Step 1) and/or the nature of the waste (Step 4). This last factor is particularly important in the industrial category.

## RATING OF THE ENDANGERMENT TO POTENTIAL WATER SUPPLIES

| Distance from potentially affected water supply (m). | # Sites with Water well down dip | # Sites with Surface water down dip | # Sites with well water up dip | # Sites with no nearby water source |
|---|---|---|---|---|
| <200 | 3,508 | 10,529 | 717 | |
| 200 - 400 | 1,956 | 4,750 | 421 | |
| 400 - 800 | 1,572 | 2,186 | 695 | |
| 800 - 1,600 | 1,070 | 1,416 | 539 | |
| TOTAL | 8,106 26% | 18,881 60% | 2,372 8% | 1,942 6% |

Table 5.6

## CHARACTERISTICS OF THE POTENTIAL ENDANGERMENT TO WATER SUPPLIES (ALL SITES)

| % Sites | AGR | MUN | IND | MNG | OAG |
|---|---|---|---|---|---|
| A. Potentially affecting a water well | 28 | 27 | 29 | 17 | 17 |
| B. Potentially affecting a Surface water | 61 | 58 | 56 | 64 | 68 |
| C. No water source down dip | 7 | 10 | 8 | 8 | 5 |
| D. No water source within 1 mile | 4 | 5 | 7 | 11 | 10 |

Table 5.7

## CHARACTERIZATION OF THE POTENTIAL ENDANGERMENT TO WATER SUPPLIES

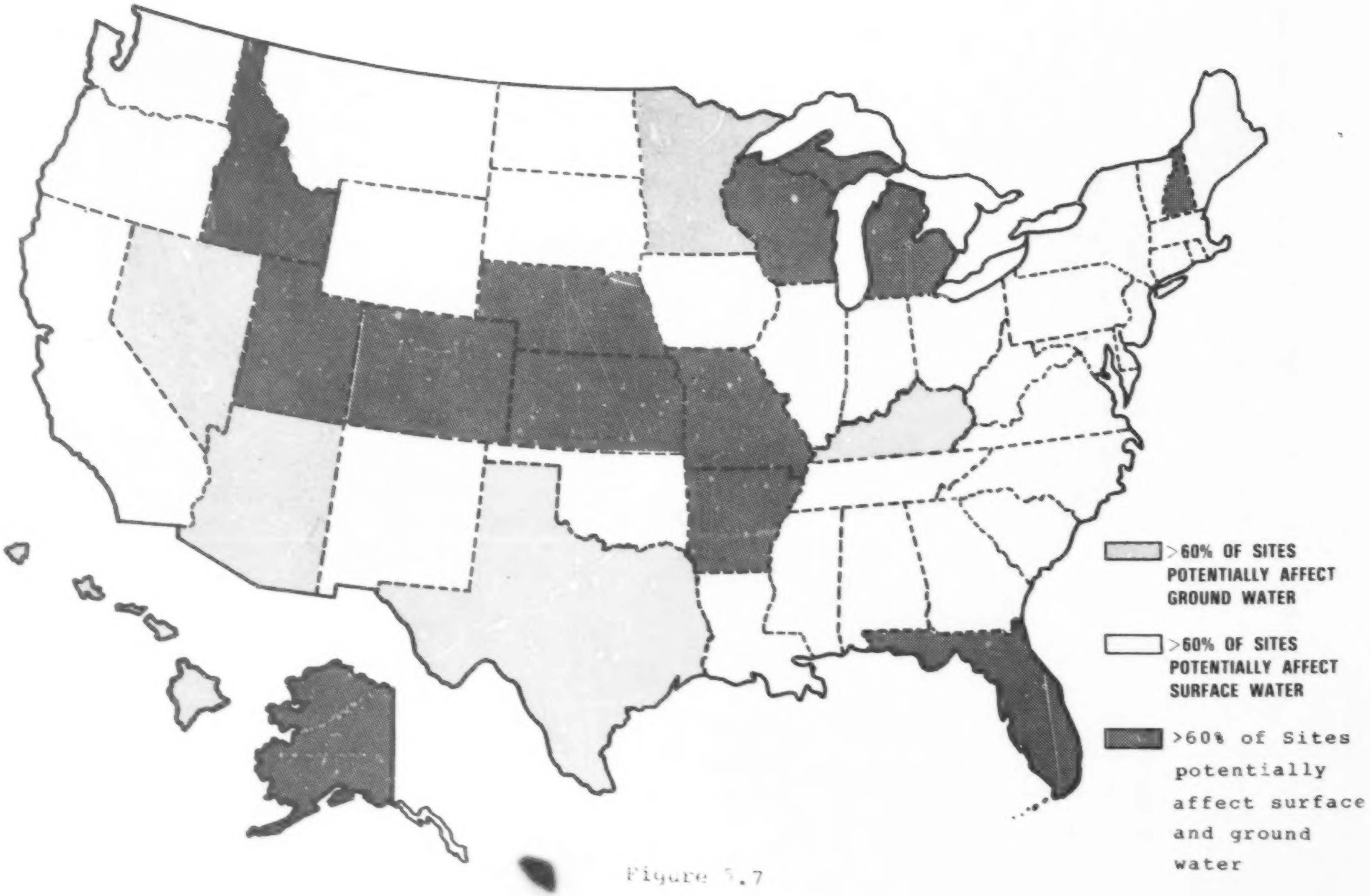

▨ >60% OF SITES POTENTIALLY AFFECT GROUND WATER
☐ >60% OF SITES POTENTIALLY AFFECT SURFACE WATER
■ >60% of Sites potentially affect surface and ground water

Figure 5.7

# CHARACTERISTICS OF THE POTENTIAL ENDANGERMENT TO WATER SUPPLIES

## (SITES IN "GROUP III" HYDROGEOLOGIC SETTING)

| Category % Sites | AGR | MUN | IND | MNG | OAG | ALL |
|---|---|---|---|---|---|---|
| A. Potentially affecting a water well | 29 | 32 | 33 | 23 | 16 | 31 |
| B. Potentially affecting a surface water * | 61 | 55 | 57 | 63 | 64 | 57 |
| C. No water source down dip | 6 | 10 | 7 | 7 | 8 | 9 |
| D. No water source within one mile | 4 | 3 | 3 | 7 | 12 | 3 |

*Although surface water is the primary supply that may be affected in B, ground water between the waste source and surface water supply would also be adversely affected.

Table 5.8

An attempt to establish a correlation between liners and Step 1 rating is shown in Figure 5.8. The figure indicates that no correlation exists.

Approximately 30 percent of the industrial sites, 22 percent of the municipal sites and 16 percent of the agricultural sites are lined, regardless of the nature of the unsaturated zone. Furthermore, the type of liner does not seem to be influenced by the siting. Clay and compacted soil liners are as prevalent in sand and gravel areas as in the tighter formations.

Similarly, Figure 5.9 shows very little correlation between the presence of a liner and the hazard potential estimated for the waste. In the mining, industrial and municipal categories, the hazard potentials of the waste cover a broad range and should have some influence over frequency of liner use. Only in the municipal category is there a significant difference between the percentage of sites lined when the waste rating is >7 (22 percent) or >7 (35 percent lined). The types of liner used do not vary however, and clay or compacted soil from the majority of liners.

The industrial category shows a slight increase in the use of artificial liners in impoundments containing wastes with a higher hazard potential, but little difference in the percentage of impoundments lined.

Finally, a comparison of lined and unlined sites in the different hydrogeologic groups shown in Figure 5.10, illustrates that there is no correlation between the natural setting and the use of liners.

Use of Monitoring Wells

The limited amount of data available on monitoring wells and the problems with the validity of the data explained in Chapter IV, make it difficult to derive any correlations. However, none could be found between the hydrogeology of the sites and the use of monitoring wells. In other words, the sensitivity of the aquifer to contamination appears to have little to do with whether it is monitored.

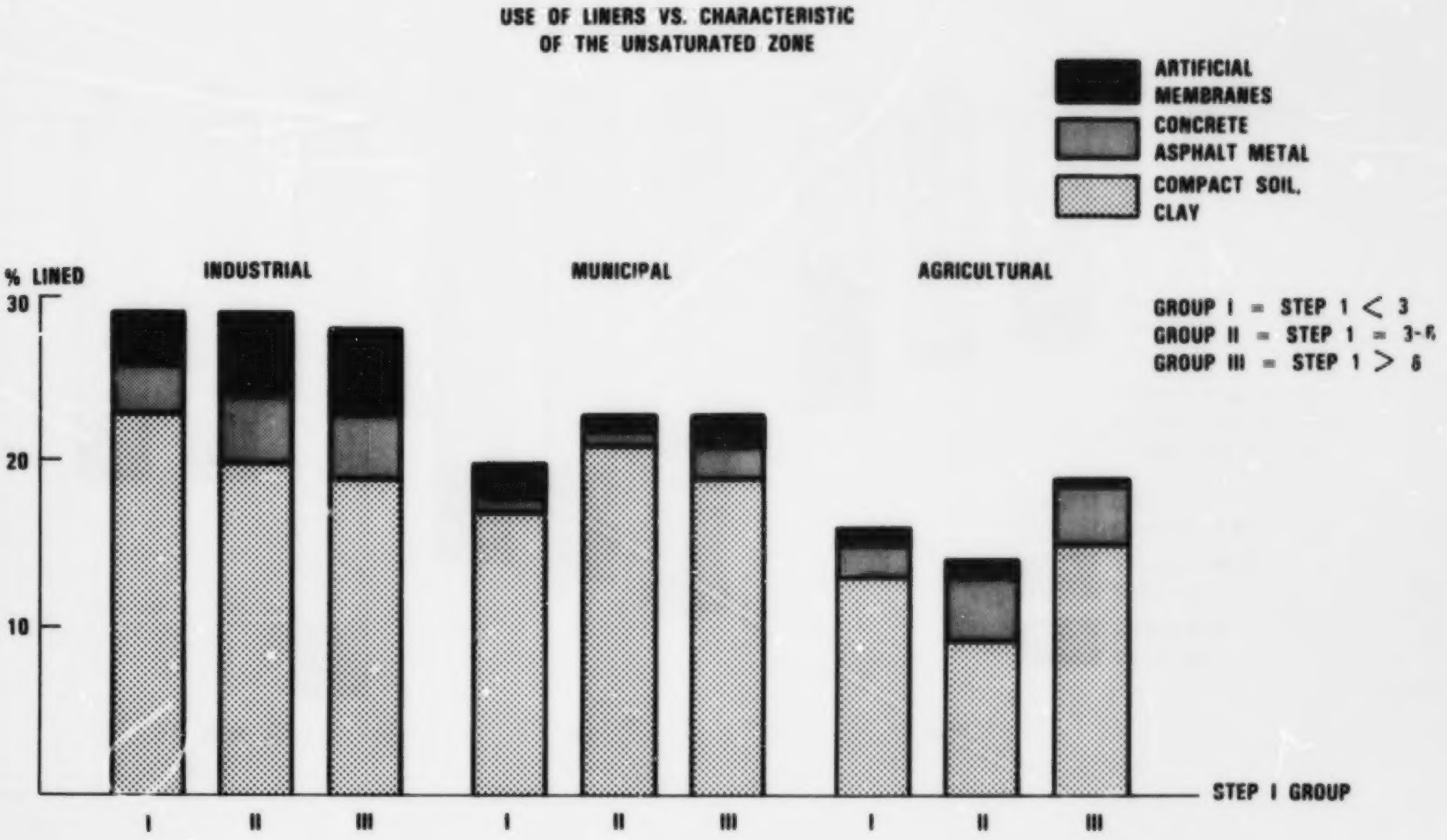

USE OF LINERS VS. CHARACTERISTIC
OF THE UNSATURATED ZONE
ARTIFICIAL MEMBRANES
CONCRETE ASPHALT METAL
COMPACT SOIL, CLAY
% LINED
30
20
10
INDUSTRIAL
MUNICIPAL
AGRICULTURAL
GROUP I = STEP 1 < 3
GROUP II = STEP 1 = 3-6
GROUP III = STEP 1 > 6
STEP I GROUP
I
II
III
I
II
III
I
II
III

Figure 5.8

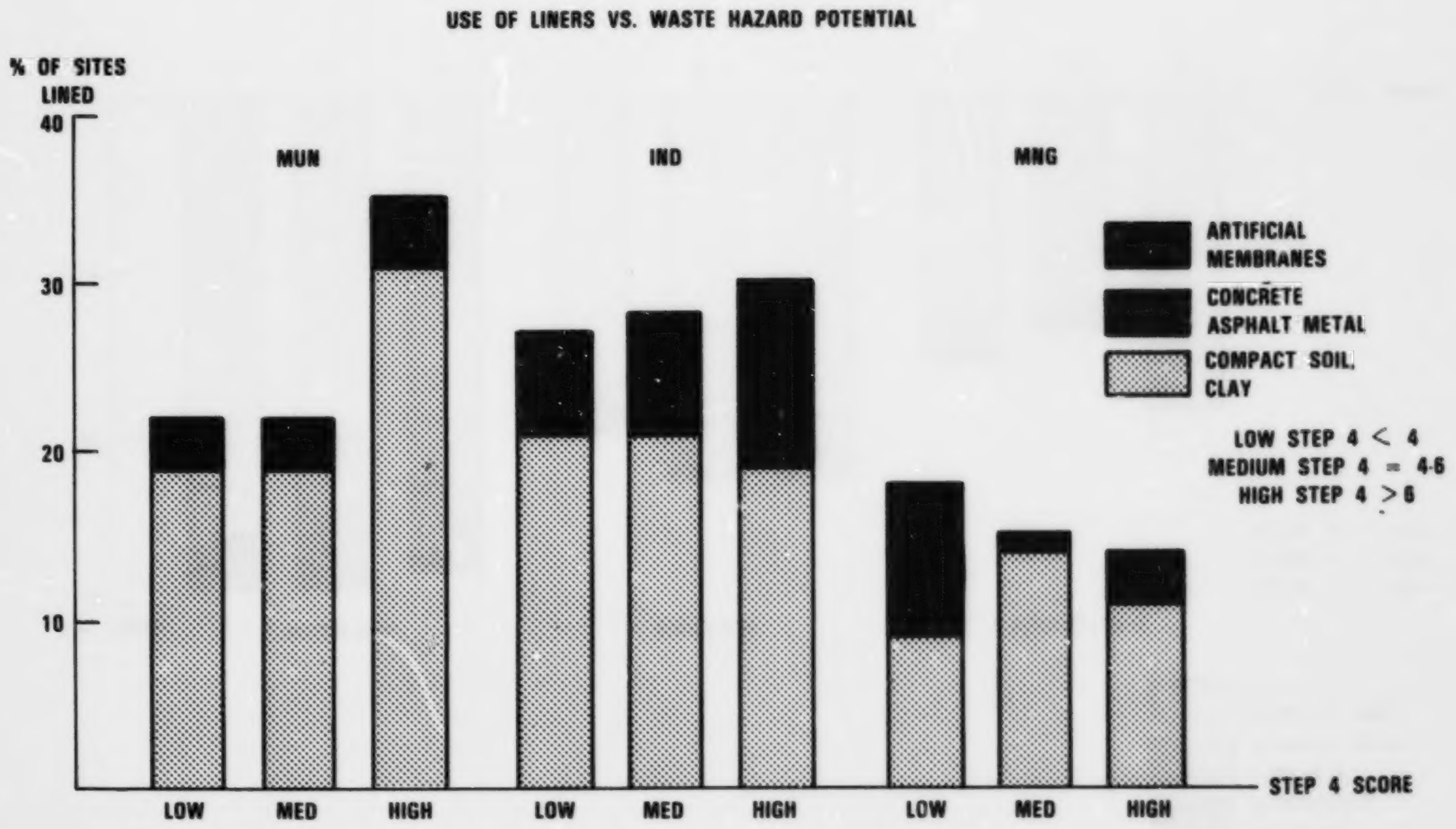
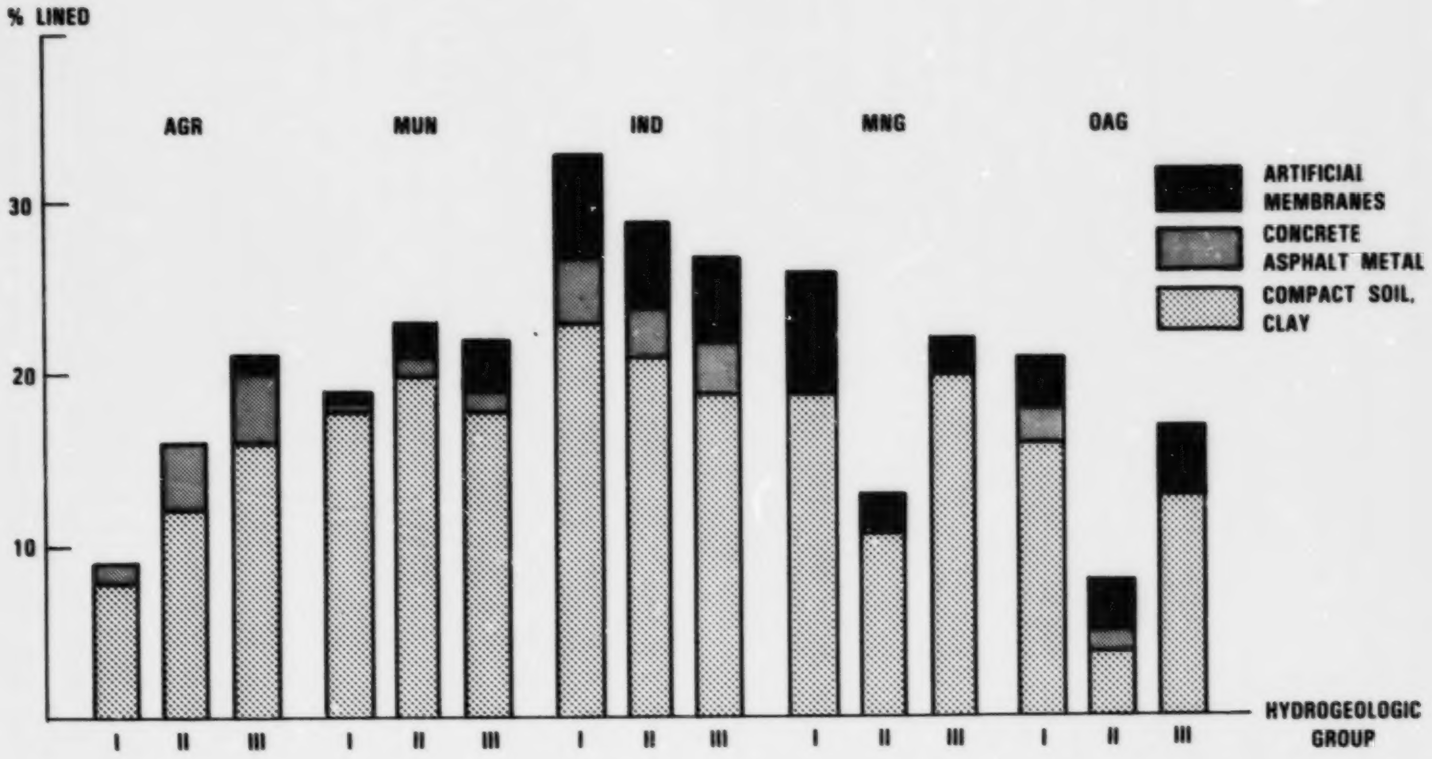

USE OF LINERS VS. WASTE HAZARD POTENTIAL
% OF SITES LINED
40
30
20
10
MUN
IND
MNG
ARTIFICIAL MEMBRANES
CONCRETE ASPHALT METAL
COMPACT SOIL, CLAY
LOW STEP 4 < 4
MEDIUM STEP 4 = 4-6
HIGH STEP 4 > 6
LOW
MED
HIGH
LOW
MED
HIGH
LOW
MED
HIGH
STEP 4 SCORE

Figure 5.9



USE OF LINERS VS. HYDROGEOLOGY

Figure 5.10

# CHAPTER VI

# CASE STUDIES OF GROUND WATER CONTAMINATION FROM SURFACE IMPOUNDMENTS

## INTRODUCTION

This chapter presents summary information on incidences of ground water contamination from surface impoundments. The data on which this summary is based were provided by the States as part of their final SIA Report. The nature of the information provided showed considerable disparity in both quality and detail, since the level of investigation performed by the States in gathering the data varied. However, in nearly all instances, States were careful to include only documented case studies that could clearly be attributed to surface impoundments. In the few instances where this was not the case, they carefully indicated the situation.

The data here are illustrative rather than comprehensive. Indeed, the case studies cited by the States are merely representative and in most cases include only a small number of the known cases of ground water contamination from surface impoundments, and do not consider contamination from other sources.

## SUMMARY OF INFORMATION PROVIDED

A total of 416 case studies were discussed in some detail in the State Reports. Several States reported an additional 143 cases but these are not included in the analysis that follows since they did not contain sufficient information. Within the data base, there are an additional 115 sites that have not been developed as case studies, since sufficient detail is not available to characterize them. However, the information is discussed briefly at the end of the chapter. Seven States provided no case studies at all. Figure 6.1 shows the geographic distribution of the 416 sites as reported by the States.

In general, States included information on four major areas: cause of contamination, method of detection, affected supplies and remedial action taken. These topics are discussed in the sections that follow.

Figure 6.2 provides a breakdown of the sites by category, with the industrial category further delineated by SIC codes. Over 60 percent of the sites fall into the industrial category and within this, over 30 percent are in "Chemical and Allied Products." This trend may not necessarily reflect poor design and siting

## LOCATION OF CASE STUDIES

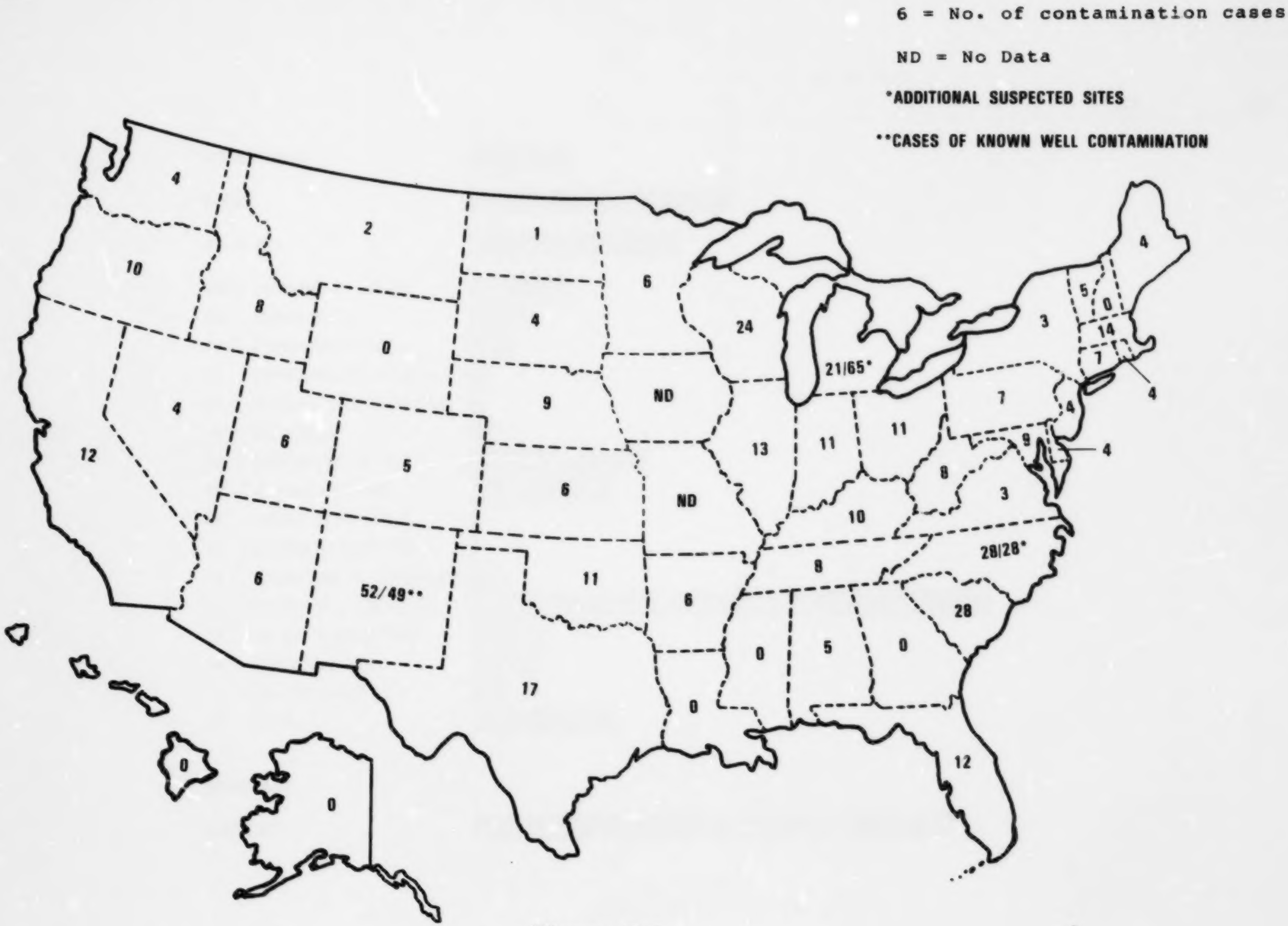

6 = No. of contamination cases
ND = No Data
*ADDITIONAL SUSPECTED SITES
**CASES OF KNOWN WELL CONTAMINATION
4
2
1
6
10
8
4
24
5
0
4
0
3
14
21/65*
7
4
9
ND
7
4
12
4
6
5
13
11
11
4
6
ND
8
3
10
28/28*
11
8
6
52/49**
6
28
0
5
0
17
0
12
0
0

Figure 6.1

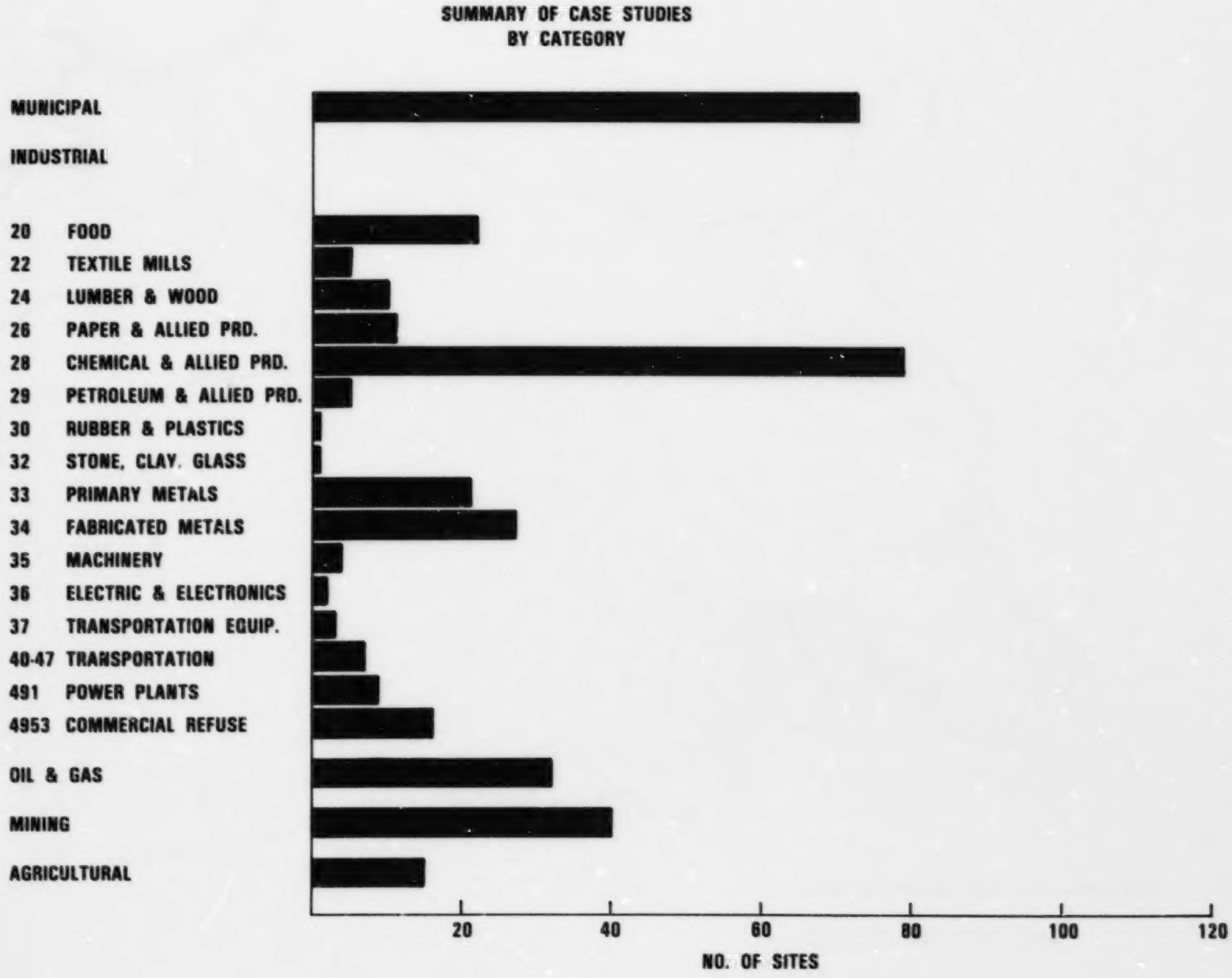

SUMMARY OF CASE STUDIES
BY CATEGORY
MUNICIPAL
INDUSTRIAL
20 FOOD
22 TEXTILE MILLS
24 LUMBER & WOOD
26 PAPER & ALLIED PRD.
28 CHEMICAL & ALLIED PRD.
29 PETROLEUM & ALLIED PRD.
30 RUBBER & PLASTICS
32 STONE, CLAY, GLASS
33 PRIMARY METALS
34 FABRICATED METALS
35 MACHINERY
36 ELECTRIC & ELECTRONICS
37 TRANSPORTATION EQUIP.
40-47 TRANSPORTATION
491 POWER PLANTS
4953 COMMERCIAL REFUSE
OIL & GAS
MINING
AGRICULTURAL
20
40
60
80
100
120
NO. OF SITES

Figure 6.2

on the part of the industrial sector; rather it may result from the fact that State programs tend to focus on industrial facilities. Of the remaining sites, just over 17 percent of the case studies are in the municipal category, 10 percent are in mining, 7 percent in oil and gas and just under 4 percent are in the agricultural category.

## ASSESSMENTS OF CASE STUDIES

Of the 416 case studies reported, 208 were assessed using the SIA rating scheme. A comparison of their Step 5 (ground-water contamination potential, see Figure 6.3) score shows that the average score for case studies was 24.4, while the average score for the entire industrial sector was 20.2. In ranking sites for further study, a Step 5 score of 22 was considered to indicate a high potential for contamination. In view of the scores for the case studies evaluated, it would appear that the case studies indicate that the rating system does discriminate potentially dangerous sites from relatively safer sites, but the system may not be sensitive enough to provide more detailed analysis.

While this is to some extent true, there are some important limitations in such an assumption. In many instances, the investigations which led to these sites being identified as case studies were prompted by the SIA score itself. Thus, it is possible that the investigation and discovery of contamination in cases was not random and it favored sites with high scores.

Second, the variation in enforcement procedures and efficacy found from State to State was frequently accompanied by concommitant variations in the conduct of the SIA. Necessarily, the rating system allows some subjectivity in site evaluations. As a result, a State that conducted an aggressive inventory and assessment program frequently assigned relatively higher scores and at the same time identified more case studies than other States. This could have the effect of tipping the results in favor of higher scores for case study sites. Nevertheless, the average Step 5 score for case studies evaluated is sufficiently greater than the same score for the system as a whole that it is supportive of the rating system.

## CAUSES OF CONTAMINATION

Information provided in the State reports pointed to four primary causes of contamination. Table 6.1 outlines the frequency with which a particular cause was cited as contributing to contamination.

Of course, defining the cause of contamination is a complex task that often involves extensive investigations conducted over a long time throughout large areas. In some cases, the

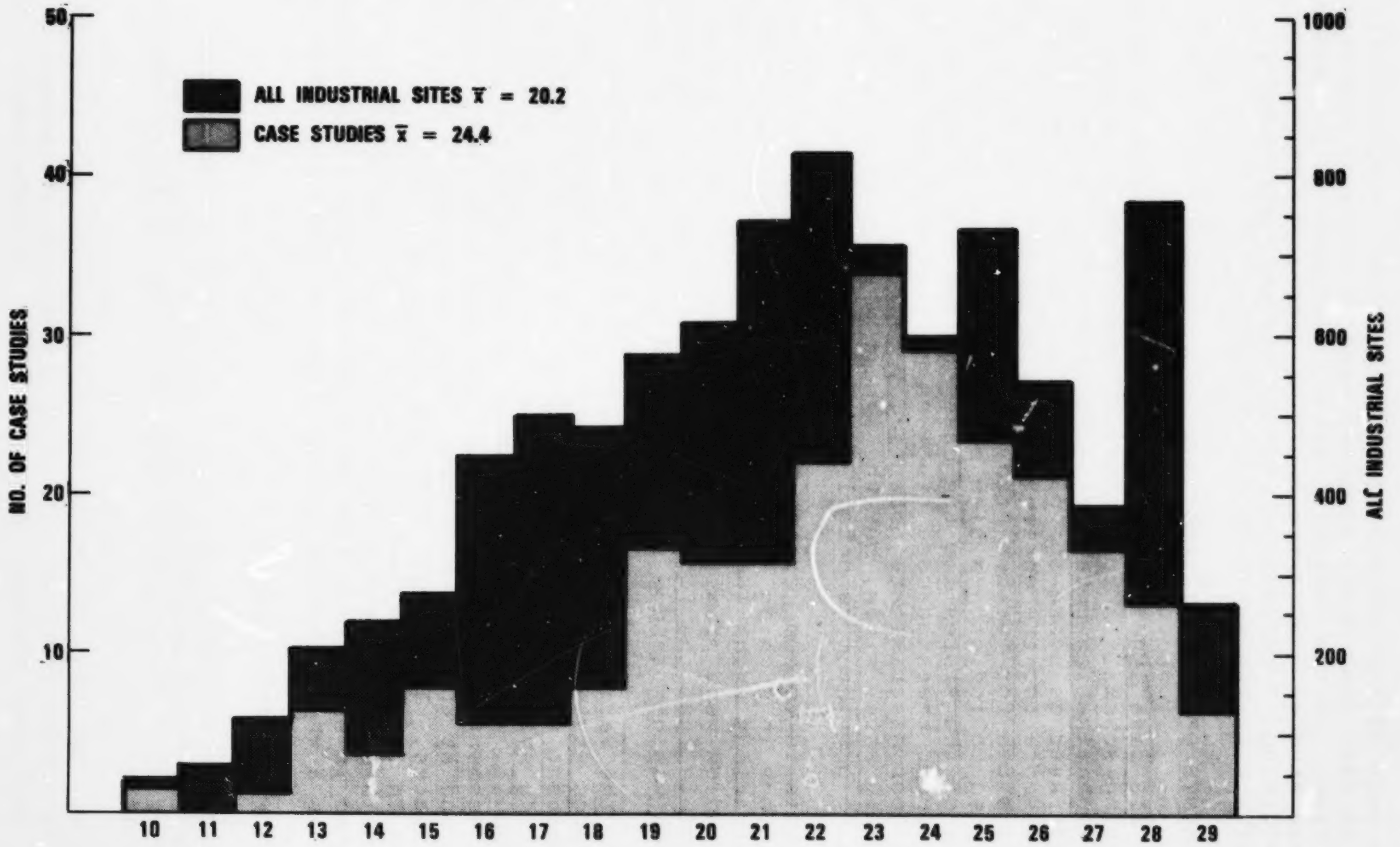

DISTRIBUTION OF STEP 5 SCORES
FOR CASE STUDIES

Figure 6.3

# CAUSES OF CONTAMINATION

| Cause | Frequency (Percent) |
|---|---|
| Seepage | 78.7 |
| Dike Failure/Overflow | 10.1 |
| Liner Failure | 7.6 |
| Catastrophic Collapse | 1.6 |
| Other | 2.0 |

Table 6.1

State reports reflected investigations of this depth; in others, either the level of detail provided or the depth of the initial study was not as comprehensive. Furthermore, just 277 of the 416 sites had data on causes of contamination. Thus, this table is valid for a general overview of causes contributing to ground water contamination but should not be viewed as definitive.

Seepage, as used in this table, refers to the direct percolation of liquids to the water table from the impoundment itself. Overflow and liner failure, which also involve seepage, are viewed separately for the purpose of this analysis. Catastrophic collapse refers here to situations where the contents contributed to enlarging solution channels or to furthering sink hole development.

A variety of causes that did not fit a particular category have been termed "Other." This category included sites in which the contents were in direct contact with ground water (and thus did not involve seepage), sites which were located over boreholes which acted as a conduit for contaminants, and other miscellaneous causes.

Of particular significanc in Table 6.1 is the incidence of liner failure. The total number of case study sites which are lined is not known, but just under 8 percent of the case studies involved liners. Leaks due to loss of liner integrity was the primary cause of liner failure. Other problems included improper installation (allowing seepage through the dikes or liner seams) displacement of membrane liners (presumably due to hydrostatic pressure), and inadequate design standards for clay liners which allowed seepage of contents through the liner (despite apparent liner integrity). This clearly indicates the need for careful design, inspection, and other quality control measures when relying on liners.

## METHOD OF DETECTION

The reported means of detecting contamination reveal a pattern of inadequate monitoring and surveillance. Figure 6.4 illustrates the means which led to discovery of ground water contamination. Just under 45 percent of the cases were not discovered until they had adversely affected water quality in supply wells and often more than one well was affected from a single instance. One case caused more than 50 domestic wells to be closed. Twelve percent of the cases either caused injury to crops, wildlife, or livestock, or contaminated surface water.

Although about 30 percent of the cases were detected by monitoring wells, many were not monitored until percolation was suspected. Moreover, less than 16 percent of the sites in

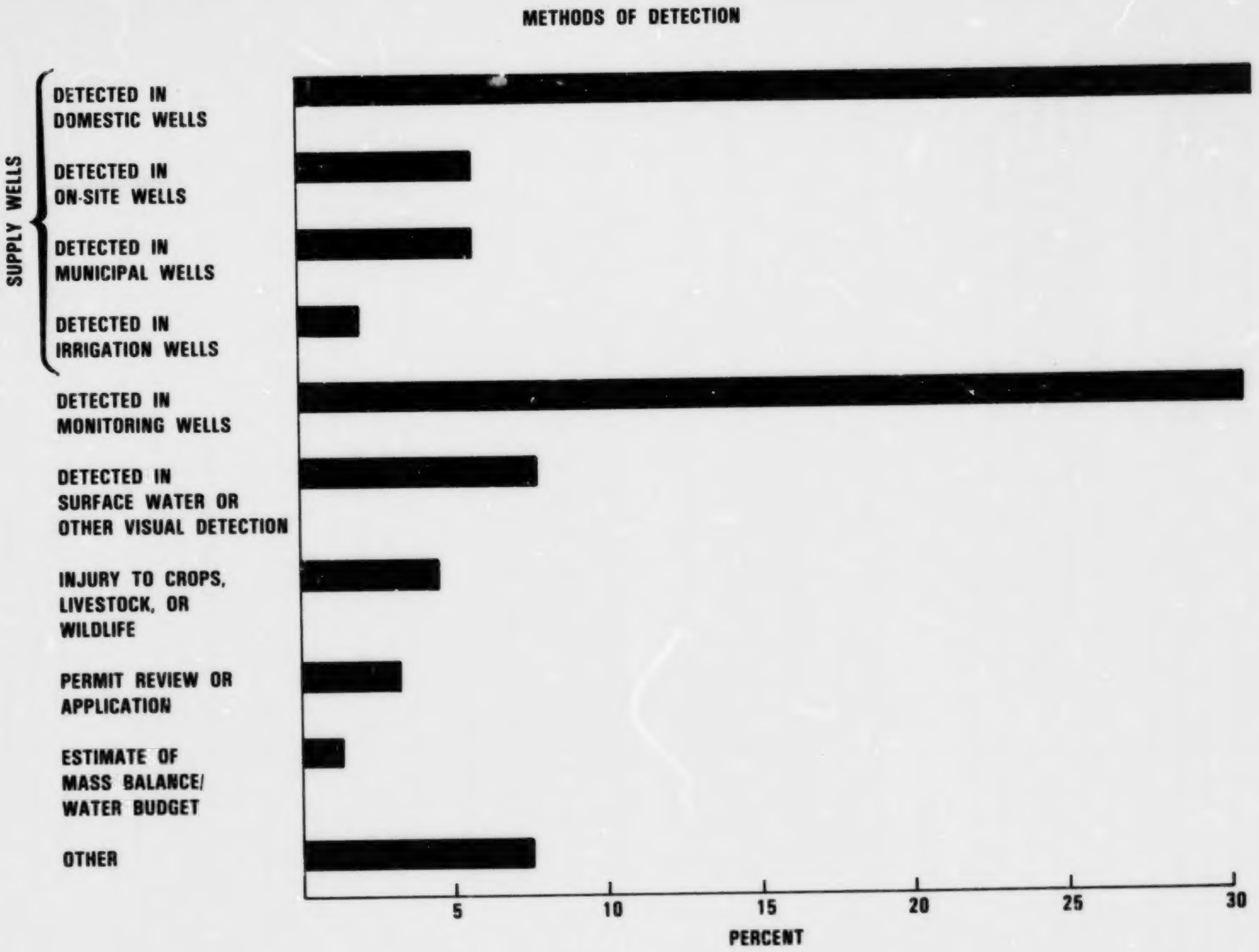

METHODS OF DETECTION
SUPPLY WELLS
DETECTED IN DOMESTIC WELLS
DETECTED IN ON-SITE WELLS
DETECTED IN MUNICIPAL WELLS
DETECTED IN IRRIGATION WELLS
DETECTED IN MONITORING WELLS
DETECTED IN SURFACE WATER OR OTHER VISUAL DETECTION
INJURY TO CROPS, LIVESTOCK, OR WILDLIFE
PERMIT REVIEW OR APPLICATION
ESTIMATE OF MASS BALANCE/ WATER BUDGET
OTHER
5
10
15
20
25
30
PERCENT

Figure 6.4

the data base as a whole are known to be monitored, and the efficacy of many monitoring programs (particularly those located in aquifers composed of crystalline or soluble rock) is open to question. Nevertheless, these figures indicate site monitoring is effective in identifying pollution at an early stage.

Review of existing permits and new applications together with rough estimates of water budgets based on available data were used as a method of detection in just 4.6 percent of the cases. Thus, contamination from unmonitored sites was identified by active intervention by authorities preceding obvious damage in less than 5 percent of the cases.

## REMEDIAL ACTION

The following options were used most frequently in sites which practiced remedial action:

- Closing the impoundment or the facility
- Monitoring the problem with further actions studied
- Improved design or engineering (such as lining or relining)
- Containing or intercepting the plume
- Treating or replacing ground water
- Pretreating the waste
- Reuse/Recycle

Only about one third of the 416 case studies contained data on remedial action. The remaining sites either have done nothing or have no data. Operators seldom used only one measure for remedial action, but more often used a combination of actions such as closure, counter pumping, and replacement of the affected water supply. Table 6.2 illustrates the frequency with which the given methods were used.

Closure, which was employed at 28 percent of the sites, for the purposes of this study includes a variety of measures ranging from simple abandonment to detailed engineering plans that incorporate waste removal and treatment, filling, grading, capping, seeding and fencing.

Of the 17 percent of the sites that lined or relined impoundments, clay was used most frequently, followed by membrane liners and finally asphalt or cement liners. In some instances, facilities attempted to seal the impoundment while full,

## SUMMARY OF REMEDIAL ACTION
## EMPLOYED AT CASE STUDY SITES

| Remedial Action | Frequency of Use (%) |
|---|---|
| Closure* | 28% |
| Line or Reline Impoundment(s) | 17% |
| Interceptor Wells, Counter Pumping Well Points, Slurry Trench etc. | 15% |
| Treat or Replace Affected Supply | 13% |
| Monitor and/or Ongoing Study | 9% |
| Treat or Pretreat Waste | 8% |
| Construct New Impoundments | 6% |
| Litigation | 2% |
| Recycle/Reuse | 2% |
| | 100%** |

*Refers to closure of impoundment(s), not necessarily company or facility.

**Only one third of the sites contained information on remedial action.

Table 6.2

using bentonite or other fine-grained admixtures; however, the majority of the sites had to interrupt operations and install the liners using conventional measures.

A surprisingly large percentage, 15 percent of the sites, used some means of intercepting or containing the plume. These can be viewed essentially as active or passive management approaches. Counter pumping, interceptor wells, barrier wells etc., represent active measures that require significant expenditures for operating and maintenance. Passive approaches include cutoff walls, french drains and intercept trenches that rely primarily on gravity and that may involve significant initial capital expenditures, but usually do not require extensive costs for operating and maintenance. With both systems, some provision is necessary for treating or disposing of the affected ground water.

Treating or replacing the affected water supply was used by 13 percent of the sites. Treatment included Granulated Activated Carbon (GAC), chlorination, and other techniques and alternative water supplies included deeper wells, increased pumping from remaining wells in municipal systems, and connection to city supplies for affected domestic supply wells.

In 9 percent of the cases, although remedial action was either planned or required, no specific course of action was possible without further study and increased monitoring. The reason for this was frequently the possibility of litigation, or the presence of complex hydrogeologic conditions that precluded obvious assessments of damage and simple remedial solutions.

Waste treatment or pretreatment, used in 8 percent of the remedial actions, consisted of lime treatment, activated carbon and granulated activated carbon, reverse osmosis, ion exchange and other treatment methods. Closely related to treatment/pretreatment were alterations in the manufacturing process designed to reuse what had been waste and/or to recover and market waste products (used for upgrading at 2 percent of the sites).

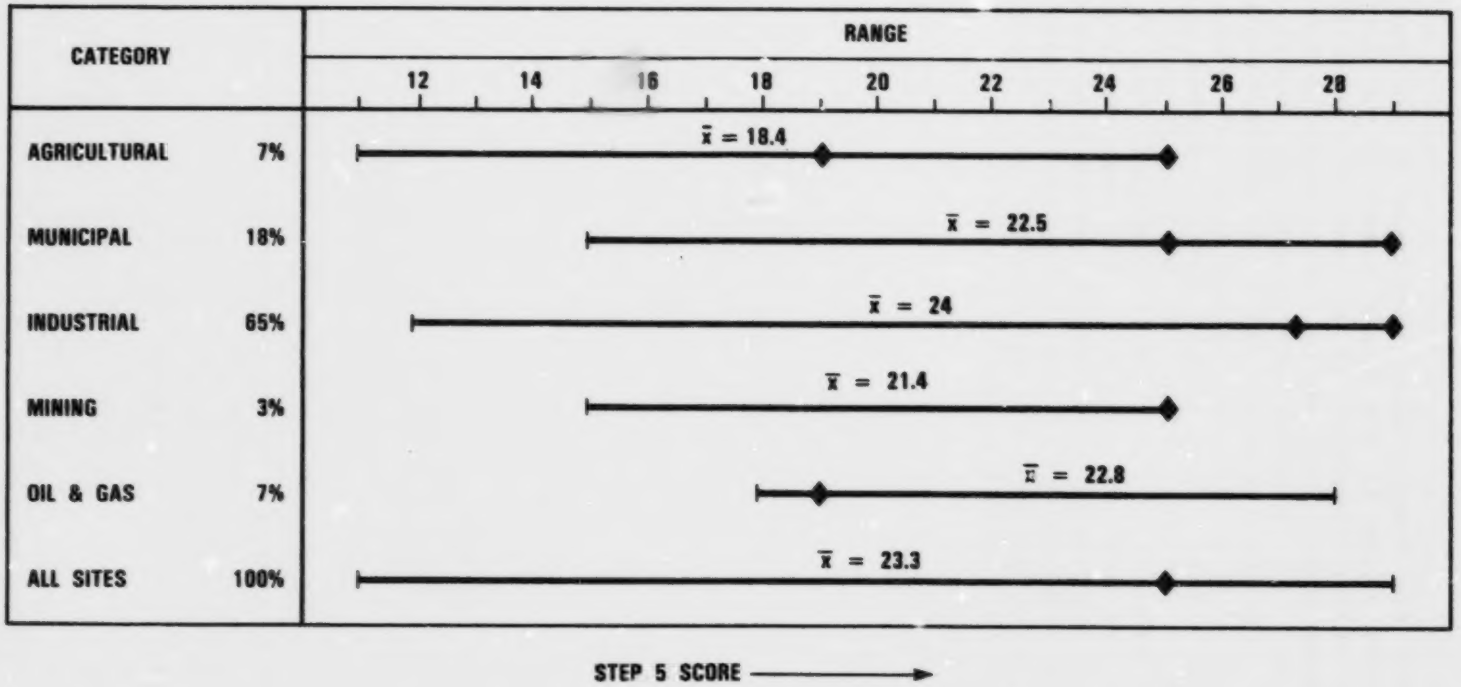
Of the remaining 8 percent, 6 percent constructed new, usually lined, impoundments and closed existing impoundments; 2% were in some stage of litigation. The later figure may be somewhat misleading, however, since two-thirds of the case studies contained no data on remedial action and these sites may be involved in some form of litigation.

## OTHER INSTANCES OF CONTAMINATION

As part of the assessment, States identified 183 instances where monitoring wells showed evidence of contamination. There is some overlap of the data presented here and the information extracted from the case studies provided in the

State reports which formed the basis for the analyses presented earlier in this chapter. Specifically, 68 listings, or just over 37 percent of these sites, were included in the preceding analyses.

Figure 6.5 presents the range, mean, and mode of the overall contamination scores (Step 5) for these sites by category. Industrial sites, which comprised 65 percent of this subset of data, had the highest mean score (24) while agricultural sites, comprising 7 percent of the data subset, had the lowest (18.4). Since these sites represent actual cases of contamination, it appears that the rating scheme emphasizes more the potential for adverse health effects than simply loss of ground water as a resource due to contamination. While this is valid for rating the hazard strictly from a health perspective, it tends to minimize the energy, economic, and resource impacts of damage to water supplies. The result may be that ratings which constitute a high potential for contaminating water supplies may not be consistent across categories. The primary problem appears to be the waste hazard rating.



MODE, MEAN AND RANGE:
STEP 5 SCORES OF CONTAMINATION CASES

Figure 6.5

# CHAPTER VII

# STATE FINDINGS

States presented conclusions and recommendations in addition to the data on active and abandoned surface impoundments. In some cases the conclusions and recommendations address a wide range of issues related to ground water quality and are not directly related to the findings of the SIA. The conclusions and recommendations presented in this chapter represent the views (written in 1979-80) of the individuals responsible for conducting the SIA and not necessarily the policy of the State.

The State-identified issues generally predate the passage and implementation of Federal initiatives such as RCRA, Superfund and the UIC program. Since these programs have been initiated, the most threatening segment of impoundments (those containing designated hazardous wastes) are beginning to be addressed. Moreover, as mentioned in Chapter 3, State programs were changing at the time the SIA was conducted, and today the problems related to ground water contamination are more widely recognized.

In this chapter, the major and often-recurring conclusions and recommendations are summarized. Not all States addressed all issues and in some cases the responses were indirect. Thus, some interpretation was necessary. Nevertheless this report attempts to reflect State positions accurately.

## Ground Water Contamination From Surface Impoundments

Ground water contamination has occurred from surface impoundments.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 44 | 93 | 7 |

There is a high potential for ground water contamination from surface impoundments.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 43 | 93 | 7 |

Surface impoundments are often poorly sited.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 39 | 90 | 10 |

Design and construction practices are inadequate.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 30 | 90 | 10 |

Operation, maintenance and monitoring practices are inadequate.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 33 | 89 | 11 |

The vast majority of States indicated that surface impoundments have already polluted ground water, and that the potential for further contamination is high. In those States indicating that contamination had not occurred or that the potential for contamination was not high, none practiced extensive monitoring of impoundments.

The problems identified by the States covered every phase--from site selection, to monitoring. Again, the majority of States indicated that current practices were not adequate, while a small percentage stated that impoundment practices were, in general, sound, although most of the latter acknowledge individual abuses.

## Effectiveness of State Laws and Regulations

Legislative authority is adequate.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 36 | 81 | 19 |

Rules and Regulations are adequate.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 40 | 35 | 65 |

Monitoring and Enforcement are adequate.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 40 | 28 | 72 |

Programs suffer from jurisdictional fragmentation and/or inadequate resources.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 30 | 70 | 30 |

The majority of the States believed that existing legislation was sufficiently comprehensive to establish effective programs. However, most of the States indicated that lack of adequate funds and a patchwork organization severely limited the effectiveness of existing programs. They cited other problems such as a bias towards surface water quality in regulations and a lack of inspection capabilities.

In those States citing jurisdictional fragmentation as a problem, the most common complaints were that agencies frequently competed for resources, that voids and duplication were often present in regulatory programs, and that communication between agencies was sparce when it occurred at all.

Impoundments in the agricultural and oil and gas category were the least regulated facilities.

## Effectiveness of Federal Programs

Federal funding is necessary to existing programs and necessary for any improvements in programs.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 26 | 96 | 4 |

Federal legislation is fragmented and/or does not adequately address groundwater contamination.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 23 | 70 | 30 |

State criticism of federal programs reflected many of the same issues as their evaluation of their own programs. They cited fragmentation, strong bias towards surface water quality, and the presence of voids in certain types of impoundments (non-hazardous) as major problems. They also cited the inflexible approach of the Federal programs and described the administrative requirements as burdensome. Several States indicated that excessive reporting and public participation requirements were counter productive, often siphoning off resources that could be applied to ground water protection. Some also believed that the relative inflexibility of many of the Federal programs did not enable the States adequately to address problems that were unique to their own circumstance, problems that emanated from specific localized hydrogeologic conditions, for example.

The most frequently mentioned programs in their critique of the Federal role were those funded under RCRA, the Clean Water Act (especially the 208 program) and the Safe Drinking

Water Act. While they were critical of the Federal role, most did not favor additional Federal legislation, and nearly all the States indicated that programs could not be run without Federal funds.

## Recommendations Regarding State Programs

New programs should be developed or existing programs improved.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 40 | 70 | 30 |

Site Selection Criteria or standards should be developed for surface impoundments.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 31 | 90 | 10 |

Design Criteria should be developed or improved for surface impoundments.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 32 | 91 | 9 |

Routine monitoring should be required either for all impoundments or at least for the high risk impoundments.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 32 | 97 | 3 |

More resources and/or better trained personnel are required to conduct an effective program.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 31 | 93 | 7 |

A permanent data base should be established for the SIA data and made available to the States.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 28 | 100 | 0 |

The majority of the States felt that new or revised programs were needed to adequately regulate surface impoundments. The specific actions needed were the establishment of criteria and standards for siting, designing, operating, maintaining and monitoring impoundments, and the reorganization of institutions to streamline regulatory efforts. However, in order to effect these changes, the States felt that additional staff and funds were necessary.

Conclusions Regarding the SIA

The SIA assessment methodology yielded an accurate first round approximation of the ground water contamination potential of surface impoundments.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 37 | 78 | 22 |

The assessment can be used to prioritize sites for further study.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 37 | 95 | 5 |

The assessment methodology contained elements that distorted the accuracy of the rating.

| # of States Addressing Issue | % in Agreement | % Disagreeing |
|---|---|---|
| 38 | 53 | 47 |

The majority of the States commenting felt that there were some problems with the rating system; however, most felt that the rating system was adequate to develop a first-round cut at defining the contamination potential of surface impoundments. The specific areas in which many States felt that the rating system needed improvement was the waste rating scheme (step 4) which was characterized by some as not sensitive enough, and as inaccurate by others. Other States noted that scores for the overall contamination potential (step 5) were consistently at the higher end of the scale, which they interpreted as being insufficiently sensitive to discriminate accurately between extremely hazardous sites and relatively safe sites. Many States felt, for example, that the system did not allow for discrimination between sites which posed a threat to health, and those that threatened the ground water quality, but had only minimal or no health impacts.

Nevertheless, most of the States felt that the methodology was sufficiently accurate to be useful in ranking sites and determining roughly the first round approximation of the contamination potential of surface impoundments. It was recommended that the assessment be field verified and the methodology refined if necessary.

In summary, it is evident that the majority of States believe that existing State laws are adequate to develop an effective program.

However, in general the States characterized regulations, funding and staffing as major problem areas. Specifically, design criteria and monitoring were the features mentioned most frequently as areas that required improvement.

While most States clearly wanted Federal involvement, there was no consensus on what form it should take. However, most favored a role that accented funding, technical assistance and research assistance, rather than additional mandatory requirements.

# CHAPTER VIII

# CONCLUSIONS

## CONCLUSIONS: STATE PROGRAMS

With a very few exceptions, State laws have not historically addressed the specific problem of ground water contamination from surface impoundments; however, they do in general provide adequate authority. In most cases, enabling legislation is general in nature and focuses primarily on surface water contamination. Such authority as does exist is derived by interpreting "waters of the State" to include ground water.

Regulations governing surface impoundments at the time of this study reflect this bias towards surface water protection. Although the majority of States require some sort of permit for most surface impoundments, the focus of the permit historically was primarily on direct discharges or on the surface impoundment as part of a treatment chain and not on seepage. A few States have established ground-water quality standards, monitoring requirements, specific siting standards, and other technical requirements, such as liner use, but even in these cases application of these requirements has often been sporadic or applicable only to new facilities.

Based on the data provided, in most cases the institutional framework for administering regulations is shared by several agencies, often without a formal coordinating mechanism. State reports said that this often resulted in interagency competition for resources, duplication of effort, and voids in responsibility and coverage.

One of the primary limitations to effective regulation of impoundments, even in cases where effective regulations and institutions are present, is the low priority and lack of qualified personnel in this area. States were nearly unanimous in citing this as a problem. They mentioned both lack of funds and lack of available qualified ground-water experts as problems in hiring adequate staff. However, increases in Federal grants related to the hazardous waste program under RCRA and other ground water protection programs such as the UIC program under the SDWA and the Superfund should help with this problem.

It is interesting to note the characteristics of State programs that had high incidences of lined sites at the time of data collection. While there are a number of other variables which may influence the incidence of lined sites (i.e. local geology, type of industry, age of impoundments, etc.) the efficacy of the State programs probably played a role in the frequency of lined sites. Pennsylvania, California, and Texas showed the highest percentage of lined industrial impoundments for States having data on more than 500 sites (See Chapter IV, Figure 4.12). The key elements of their programs are outlined in Table 8.1.

These three States exhibit clearly defined areas of responsibility for the institutions that are charged with regulating impoundments. They are developing and have established technical requirements (such as siting requirements, ground water quality standards, monitoring requirements, and maximum permeabilities). They may permit both direct discharges and indirect discharges, and they have established some form of waste classification (See Table 8.1). The latter may be an important component of their programs because it allows these States to rank sites and use limited resources more efficiently. Although the majority of States indicated that Federal funding was required to run effective, adequately staffed programs, there was no consensus on how constructive Federal legislation, regulations, and programs have been. Three common themes were expressed in State assessments of Federal programs:

- Most States rely heavily on Federal funds to administer programs.
- Federal programs are characterized by many States as inflexible and sometimes burdensome.
- The existing Federal programs must be integrated and a more coordinated approach between programs is desirable.

The States mentioned RCRA, the SDWA, and the CWA as the Federal programs having the greatest impact on regulation of surface impoundments. As a result of these Acts and an increased awareness of the importance of ground water as a supply source, many States are considering further legislation or are upgrading existing regulations to better address the problem of ground water contamination.

## CONCLUSIONS: LOCATION AND COUNT

### Inventory

The data from the location and count phase of the SIA indicate that oil and gas sites are the most numerous category, followed by municipal, agricultural, industrial and mining. Municipal and industrial sites tend to be in close proximity to population centers and also have more impoundments per site on the average. Accordingly, their potential impact, in terms of the number of people who could be affected by any contamination that occurs, may be greater than other categories.

ELEMENTS OF SELECTED STATE PROGRAMS

| | | | | |
|---|---|---|---|---|
| California - | Lead Agency: WQCB with Regional Boards. Areas of Responsibility are clearly defined. | Empowered to protect "Waters of the State"; includes by definition groundwater. Permits both direct and indirect discharges. | Ground water quality standards; waste classification; siting (maximum permeability); may require lining and monitoring. | Annual Inspection of Permitted Facilities. |
| Texas - | Two: Texas Division of Water Resources (TDWA) and Texas Railroad Commission (TRRC). Distinct areas of responsibility. | Empowered to protect "Waters of the State" includes by definition Groundwater. Permits both direct and non-discharging impoundments | Distinct requirements based on waste type; siting requirements 10-7 cm/s; may require monitoring or lining; extensive statewide monitoring network. | Field Inspection for Selected Facilities. |
| Pennsylvania - | Lead Agency: Bureau Water Quality Management with Oil and Gas under a second Agency. | Empowered to protect "Waters of the State" includes by definition Groundwater. Permits all facilities above a minimum capacity. | Currently developing Ground water quality standards; distinct requirements based on waste type; siting standards, (maximum permeability) | Semi-Annual Inspection |

Table 8.1

Data on the quality and quantity of the influent and effluent fluids were sometimes unavailable and States generally indicated a low confidence rating on the validity of such information. They thought data on impoundment size was somewhat more valid, and on the average, mining and industrial impoundments tended to be larger.

## Ground Water Protection

Less than 30 percent of the industrial impoundments are lined and fewer are lined in other categories. Similarly, monitoring is conducted at very few sites on a national level, although a few States require monitoring more frequently.

The study indicated that the main correlation that existed between increased use of liners and monitoring reflected variations of requirements in State programs, rather than the relative danger of the practice. For example, liner use should increase in sites that are located over usable aquifers within thin or permeable unsaturated zones. Similarly, more liners should be used when the waste is relatively more hazardous. However, the data showed no correlation between the hydrogeology of a site and the frequency of liner use and only a slight correlation between the waste hazard rating and liner use.

One factor that influenced the frequency of liner use was the relative age of the impoundment. Newer impoundments were more likely to be lined than older ones. Presumably this reflects the impact of recent legislation, as well as an increasing reliance on ground water as a water supply. In general, States which had a relatively higher percentage of impoundments lined also had more monitoring at sites. (Florida is an exception, with relatively few sites lined, but a high number of sites monitored.)

## CONCLUSIONS: ANALYSES OF DATA

The analyses indicate that surface impoundments are often sited in a way that allows percolation of wastes to the ground water. In addition, they often are lacking in design safeguards and monitoring, and are located in close proximity to water supplies. The use of siting and design safeguards shows little or no correlation with waste hazard potential or sensitive hydrogeologic settings. Indeed, patterns for both liner use and frequency of monitoring showed a greater correlation to State boundaries than to technical criteria which indicates little past attention to potential impacts on ground water.

Viewed from the perspective of specific categories, the industrial category shows the greatest contamination potential, with a mean Step 5 score of 20.4. Municipal sites followed with a mean score of 19.6. Moreover, municipal and industrial sites are generally located in proximity to both population centers and water supply systems. Beyond this, about 35 percent of the industrial sites contain waste which scored greater than 6 on the hazard potential rating. This rating is indicative of potentially hazardous waste. Summarizing these analyses, the data reveal the following:

## Site Selection

- Nearly 50 percent of all sites are located on unsaturated zones that are either very thin or very permeable. For industrial categories, more than 50 percent are so sited.
- Approximately 70 percent of all sites are located over thick and very permeable aquifers that allow rapid movement of plumes. For the industrial category the percentage rises to nearly 80 percent.
- Over 30 percent of all sites are located in areas that have thin or permeable unsaturated zones, overlie highly transmissive aquifers containing water that is currently used or of high quality. For the municipal and industrial category, the percentages rise to approximately 40 percent. Less than 10 percent of all sites are located in a manner that poses little threat of ground water contamination.

## Waste Characteristics

- Over 15 percent of all sites (excluding oil and gas) contain waste which received waste rating scores that indicate a high potential for noxious or toxic waste. In the industrial category, about a third of the sites contain potentially toxic waste.

## Proximity to Water Supplies

- Approximately 85 percent of all sites are located within one mile of a potential surface or ground water source.

## Gound Water Protection

- Approximately 30 percent of the industrial sites are lined, 20 percent of the municipal sites are lined, and 15 percent of the agricultural sites are lined. There is little or no correlation between the waste hazard, the siting characteristics and the use of liners.

- Data on monitoring also show little correlation between the sensitivity of the aquifer to contamination and the use of monitoring wells.

## CONCLUSIONS: CASE STUDIES

Analysis of the case studies points to the following: surface impoundments--whether they are termed evaporation ponds, holding ponds, etc.--have contaminated ground water when careful siting, design and operation were not practiced. Analysis of the causes of contamination shows, further, that liners and other design measures, by themselves, are no assurance that an impoundment will perform satisfactorily. There should be a well planned program of inspections, maintenance, and monitoring in order to assure satisfactory performance and adequate protection.

Use of monitoring practices seems to be inadequate, with detection occuring only as a result of contamination of the water supply in 45 percent of the cases. Moreover, in some cases when monitoring wells are employed, there is no assurance that detection will be adequate to prevent contamination of supply wells. Beyond this, the case studies indicate that remedial approaches, while practiced, require extensive study and often involve difficult legal determinations.

Finally, the Step 5 scores indicate that the rating system used in the SIA may be generally valid for its stated purpose: a first-round approximation of the contamination potential that can be useful in large aggregates but that cannot be applied to site-specific situations. It appears, however, that the rating system could be improved by increasing its sensitivity. The difference in overall contamination sources between industrial sites known to contaminate ground water and the mean score for all sites was only 3.8 out of a possible 29.

## CONCLUSIONS: STATE FINDINGS

It is evident that the majority of States believe that existing State laws are adequate to develop an effective program.

However, in general the States characterized regulations, funding and staffing as major problem areas. Specifically, design criteria and monitoring were the features mentioned most frequently as areas that required improvement.

While most States clearly wanted Federal involvement, there was no consensus on what form it should take. However, most favored a role that accented funding, technical assistance and research assistance rather than additional mandatory requirements.

# APPENDIX A

# PREFACE

The Manual for Evaluating Contamination Potential of Surface Impoundments was prepared specifically for implementing a standardized evaluation system for the EPA Office of Drinking Water Surface Impoundment Assessment (SIA) and serves as the training manual for that assessment. The SIA evaluation system set forth in the manual is based upon the previous work by Harry E. LeGrand who began over 15 years ago to develop a standardized, consistent approach to the selection of proper waste disposal sites. This system departs from the LeGrand system in order to accommodate certain philosophical differences concerning ground-water protection and specific technical aspects related to surface impoundments. In no way does this detract from the importance of the LeGrand system in serving as the basis for the SIA evaluation system.

This manual also was prepared with the assistance of the SIA work group who made many valuable suggestions. The work group members are:

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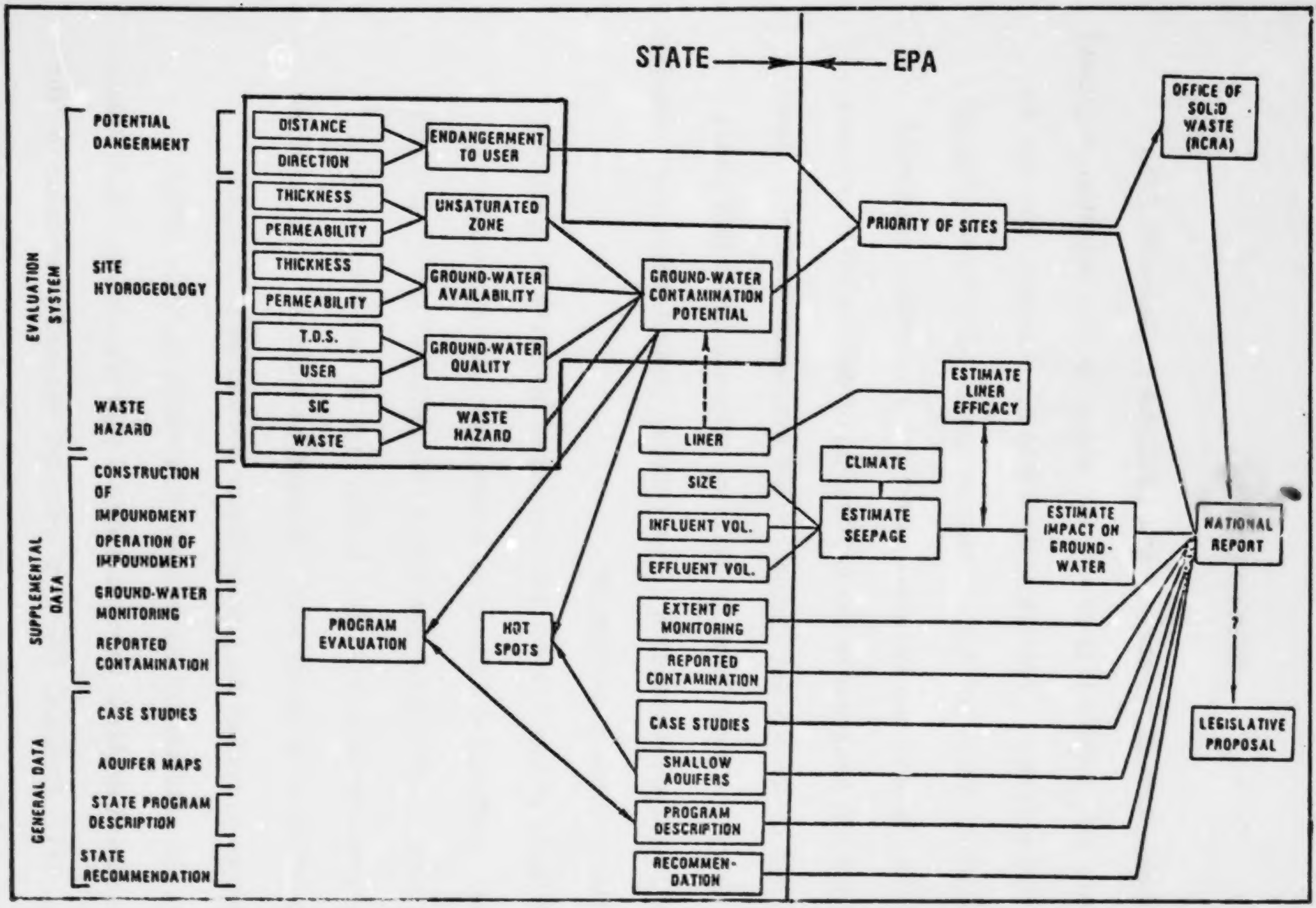
# INTRODUCTION

An objective of the surface impoundment assessment (SIA) program (see Figure 1) is to rate the contamination potential of ground water from surface impoundments and to develop practices for the evaluation of different surface impoundments (elsewhere referred to as pits, ponds, and lagoons). One of the activities conducted under the SIA program is the application of the evaluation system described in the present manual. This evaluation system applies a numerical rating scheme to different impoundments that yields a first round approximation of the relative ground-water contamination potential of these impoundments.

The basis of this system was developed by Harry E. LeGrand in 1964. LeGrand and Henry S. Brown expanded and improved the system in 1977 under contract to the Office of Drinking Water. The present system described in this manual has been modified by the Office of Drinking Water through consultation with LeGrand and Brown to reflect its ground-water protection philosophy. Before the selection of the present evaluation system, other standardized systems were considered (Cherry, et. al., 1975; Pinder, et. al., 1977; Phillips, 1976) but were not deemed as suitable for the purposes of the assessment. The system is designed to provide an



STATE
EPA
EVALUATION SYSTEM
POTENTIAL DANGERMENT
SITE HYDROGEOLOGY
WASTE HAZARD
SUPPLEMENTAL DATA
CONSTRUCTION OF IMPOUNDMENT
OPERATION OF IMPOUNDMENT
GROUND-WATER MONITORING
REPORTED CONTAMINATION
GENERAL DATA
CASE STUDIES
AQUIFER MAPS
STATE PROGRAM DESCRIPTION
STATE RECOMMENDATION
DISTANCE
DIRECTION
THICKNESS
PERMEABILITY
THICKNESS
PERMEABILITY
T.D.S.
USER
SIC
WASTE
ENDANGERMENT TO USER
UNSATURATED ZONE
GROUND-WATER AVAILABILITY
GROUND-WATER QUALITY
WASTE HAZARD
GROUND-WATER CONTAMINATION POTENTIAL
PROGRAM EVALUATION
HOT SPOTS
LINER
SIZE
INFLUENT VOL.
EFFLUENT VOL.
EXTENT OF MONITORING
REPORTED CONTAMINATION
CASE STUDIES
SHALLOW AQUIFERS
PROGRAM DESCRIPTION
RECOMMENDATION
PRIORITY OF SITES
ESTIMATE LINER EFFICACY
CLIMATE
ESTIMATE SEEPAGE
ESTIMATE IMPACT ON GROUND-WATER
OFFICE OF SOLID WASTE (RCRA)
NATIONAL REPORT
?
LEGISLATIVE PROPOSAL

Figure 1. Flow chart of the Surface Impoundment Assessment. The outlined portion is the evaluation system described in this manual.

approximation of the ground-water contamination potential of impoundments at a minimum cost. Precise, in-depth investigations of actual ground-water contamination from surface impoundments (i. e., drilling, etc.) would be too costly and time-consuming and are not involved in this first-round site evaluation. The specific site investigations into actual contamination would begin after this assessment is finished in order to optimize expenditures. Those sites identified as high contamination potential would be addressed first.

The philosophy guiding the development of this surface impoundment evaluation system is that underground drinking water sources must be protected for both present and future users as intended by Congress in the Safe Drinking Water Act, 1974. Ground-water pollution occurs when contaminants reach the water table (saturated zone) beneath the site. This is contrary to the commonly held view that ground-water contamination cannot legally be determined until the contaminated ground water crosses the property boundaries of the facilities. EPA believes that in order to protect the nation's ground-water resources it is necessary to identify potential contamination at the source where preventive measures may be initiated. The purpose of this evaluation system is to rank impoundments in terms of their relative ground-water contamination potential. The evaluation system considers several hydrogeologic parameters in the rating of the site. There are numerous parameters that may be used in evaluating a site. However, many of these parameters are related and their simultaneous consideration would be redundant. Thus, only selected parameters representative of different processes, have been included. The present evaluation system provides a standardized methodology which will ensure more consistent national results.

The parameters used in the present SIA system have been separated into two distinct groups which correspond to the two phases of the evaluation, i. e., 1) the rating of the ground water contamination potential itself and 2) the rating of the relative magnitude of potential endangerment to current users of underground drinking water sources. The parameters considered unique in rating the ground-water contamination potential are 1) the thickness of the unsaturated zone and the type of earth material of that zone, 2) the relative hazard of the waste, and 3) the quantity and quality of the underground drinking water source beneath the site. The parameters considered unique in determining the rating for the potential for endangerment of currently used water resources include: 1) the type of water source, i. e. ground water or surface water, 2) whether that water source is in the anticipated flow direction of the contaminated ground water (if such contamination occurred); and 3) the distance between the potential contamination source and the water source. These parameters account for the basic processes and factors which determine the contamination potential of the site and which indicated the relative threat to underground drinking water sources.

The level of contamination of ground water is subject to varying degrees of attenuation as the water flows through the unsaturated zone and on through the aquifer; however, the evaluation focuses on the potential for contamination of underground water sources. Attenuation mechanisms are very complex, varying with the type of waste, earth material, and physico-chemical environment. A general site evaluation system concerned with an approximation of the contamination potential cannot consider the specific attenuative capabilities of different earth materials for different wastes, particularly since there exists a vast variety of complex wastes possible. This evaluation system therefore treats attenuation in an indirect manner by considering it in combination with permeability.

The evaluation is performed in a sequence (see Figure 2). The first four steps involve the evaluation of the potential for ground water to be contaminated by rating the site's hydrogeology and waste character. The fifth step then determines the site's overall contamination potential relative to other rated sites by combining the first four steps. It must be stressed that this overall rating will express only a site's hydrogeologic

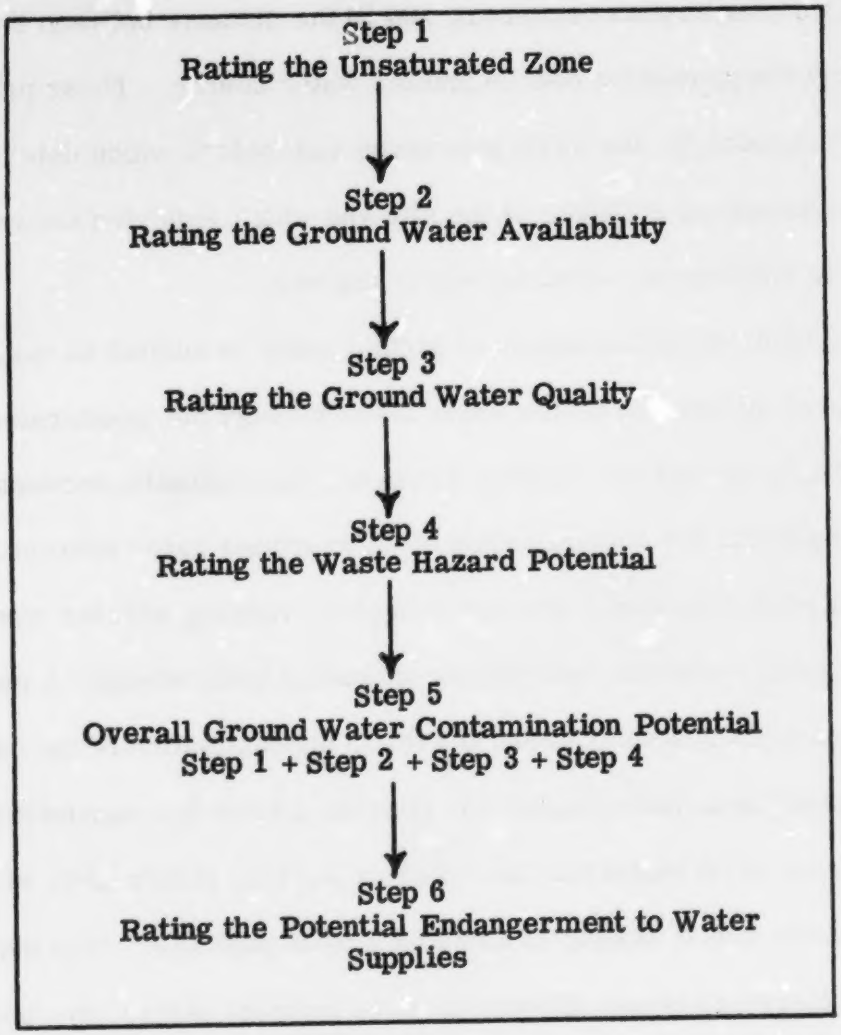

Step 1
Rating the Unsaturated Zone
Step 2
Rating the Ground Water Availability
Step 3
Rating the Ground Water Quality
Step 4
Rating the Waste Hazard Potential
Step 5
Overall Ground Water Contamination Potential
Step 1 + Step 2 + Step 3 + Step 4
Step 6
Rating the Potential Endangerment to Water Supplies

**Figure 2. Generalized sequence of steps involved in the SIA evaluation system.**

conditions relative to those conditions for all possible sites, and does not relate to a site's absolute degree of ground-water contamination. Such determination of actual contamination involving ground-water monitoring and sampling procedures must be made following site specific investigations. This system allows the investigator to assign priorities to sites on the basis of contamination potential so that the investigator could then concentrate resources upon the further investigation of these sites that rank highest in terms of their contamination potential.

Precise data is not necessary for the application of the SIA evaluation system. Performing precise measurements of the the depth to the water table, the character of the earth materials underlying the site, the hydrogeology at the site, etc., can be costly and time consuming. It must be remembered that this evaluation system is a first-round approximation and therefore estimates based on the best available information will be used with the expectation that they will provide satisfactory results for first-round evaluations.

# STEP 1

## GUIDANCE FOR RATING THE UNSATURATED ZONE

The earth material characteristics of the unsaturated zone underlying the surface impoundment are rated to determine the potential for contaminants to reach the water table. This step involves the combined rating of a) the thickness of the unsaturated zone, and b) earth material (both consolidated and unconsolidated rock) in the unsaturated zone (see Table I).

Step 1, Part A, Determination of the depth to the saturated zone for Step 1

Contaminants attenuate to varying degrees as they migrate down through the unsaturated zone, depending upon the thickness and the type of earth material. Therefore, more favorable conditions exist where the water table is deeper. The depth to the saturated zone is the depth from the base of the surface impoundment to the water table. This depth may be measured to the water table in unconfined aquifers (See Site 1 in Figure 3) or, in the case of a confined aquifer, to the top of the confined aquifer (See Site 2 in Figure 3). Where a perched water table is known to occur, the depth may be measured

# TABLE I

Step 1. Rating of the Unsaturated Zone.

GUIDELINES FOR DETERMINING CATEGORY

| Earth Material Category | I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|
| Unconsolidated Rock | Gravel, Medium to Coarse Sand | Fine to Very Fine Sand | Sand with $<15\%$ clay, Silt | Sand with $>15\%$ but $\leq 50\%$ clay | Clay with $<50\%$ sand | Clay |
| Consolidated Rock | Cavernous or Fractured Limestone, Evaporites, Basalt Lava Fault Zones | Fractured Igneous and Metamorphic (Except Lava) Sandstone (Poorly Cemented) | Sandstone (Moderately Cemented) Fractured Shale | Sandstone (Well Cemented) | Siltstone | Unfractured Shale, Igneous and Metamorphic Rocks |
| Representative Permeability<br>in gpd/ft$^2$ -<br>in cm/sec - | $>200$<br>$>10^{-2}$ | $2 - 200$<br>$10^{-4} - 10^{-2}$ | $0.2 - 2$<br>$10^{-5} - 10^{-4}$ | $<0.2$<br>$<10^{-5}$ | $<0.02$<br>$<10^{-6}$ | $<0.002$<br>$<10^{-7}$ |
| RATING MATRIX | | | | | | |
| Thickness of the Unsaturated Zone (in Meters) $>30$ | 9A | 6B | 4C | 2D | 0E | 0F |
| $>10$ $\leq 30$ | 9B | 7B | 5C | 3D | 1E | 0G |
| $>3$ $\leq 10$ | 9C | 8B | 6C | 4D | 2E | 0H |
| $>1$ $\leq 3$ | 9D | 9F | 7C | 5D | 3E | 1F |
| $>0$ $\leq 1$ | 9E | 9G | 9H | 9I | 9J | 9K |

to it rather than the underlying regional water table (See Site 3 in Figure 3). The investigator will decide whether to measure the depth to the perched water table or ignore it and measure to the regional water table. This decision should be based on the extent and thickness of the perched water table and its usefulness as a drinking water source. If the perched water table is currently being utilized as a drinking water source, the depth should be measured to it.

Water tables fluctuate on a diurnal, seasonal and annual basis due to natural and artificial causes. For this assessment system the depth to the water table should be determined on the basis of the seasonal high water table elevation. As is shown in Table I, the depth determination does not have to be exact since the intervals are large. Illustrations of possible well hydrographs are shown in Figures 4 and 5. Figure 4a depicts a hydrograph of a well in Illinois which is only affected by seasonal climatic variation. The depth to water table would be taken as approximately five feet (1.6 meters). In Figure 4b the well hydrograph illustrates a water table which is affected by seasonal pumping variation. Pumping is greatest and, as a result, the water table is lowest during May through September, the hot season when consumption

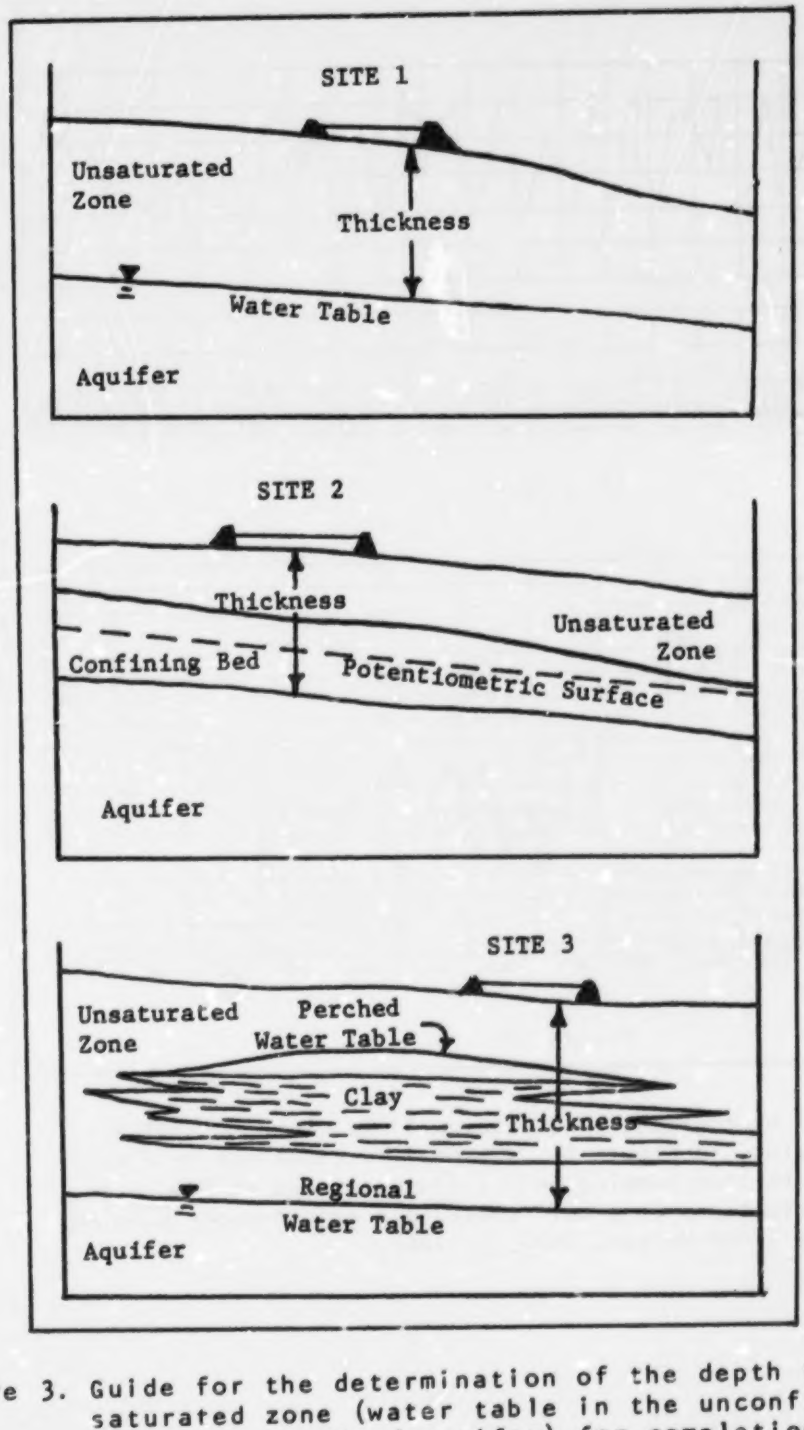

SITE 1
Unsaturated Zone
Thickness
Water Table
Aquifer
SITE 2
Thickness
Unsaturated Zone
Confining Bed
Potentiometric Surface
Aquifer
SITE 3
Unsaturated Zone
Perched Water Table
Clay
Thickness
Regional Water Table
Aquifer

Figure 3. Guide for the determination of the depth to the saturated zone (water table in the unconfined case or top of confined aquifer) for completion of Step 1.

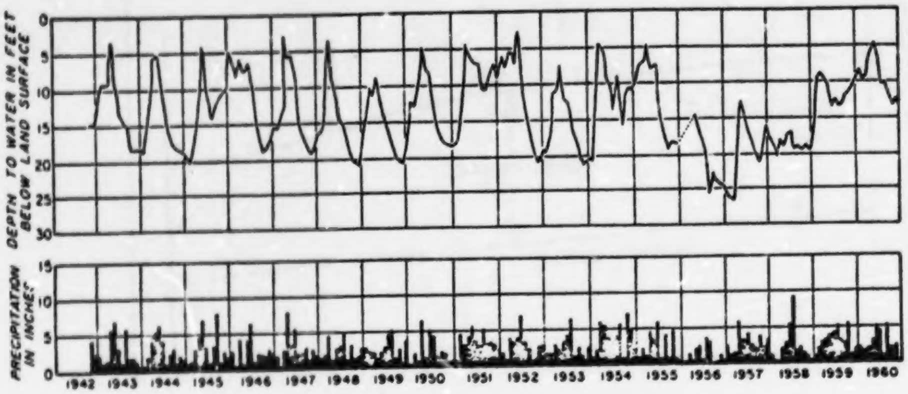


Figure 4A

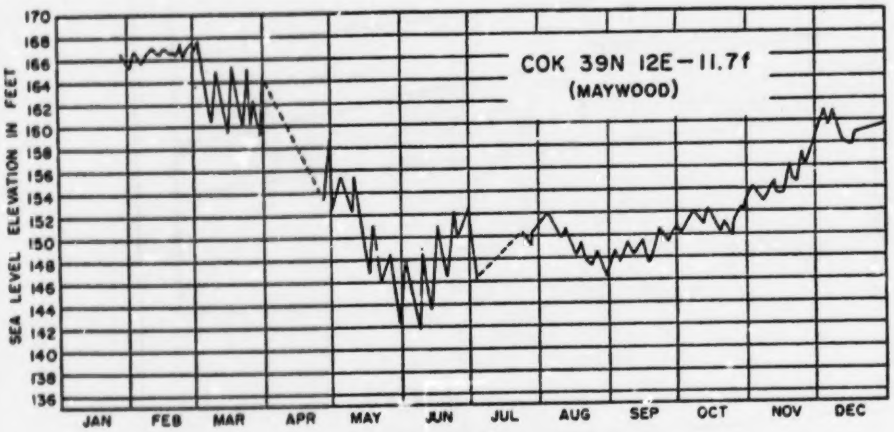


Figure 4B

Figure 4. Well hydrographs of a water well at Maywood, Illinois, showing, in Figure 4A, seasonal fluctuations in a well remote from pumping well influences; and in Figure 4B, fluctuations in a well close to a ground water pumping area (from Walton, 1970, p. 106).

is greatest. During the winter months of November through March the demand decreases and the ground-water table recovers. In this case the depth to the water table would be computed at the highest level, at 168 feet (51.2 meters) of elevation rather than the summer levels of 142 feet (43.3 meters).

Figure 5 shows a long period of record for a well hydrograph located in Ainsworth, Nebraska, in which annual and longer term fluctuations exist. Although the maximum change in water level amounts to only about 6 or 7 feet (2 meters), other areas of the country do experience much greater variation and should be considered. However, in this example, the water level used in determining the depth to the water table should be the higher level of 34 feet (10.4 meters) below the surface. Note that in all these examples, the more conservative estimate is used for depth to the water table.

In the situation where a confined (artesian) aquifer is encountered below a disposal site and an unconfined (water table) aquifer does not exist, the depth is measured to the top of that confined aquifer. Due to the nature of the confined aquifer, the net hydrostatic head of the system may decrease the possibility of contamination. However, conditions are not steady-state and other phenomena may affect the

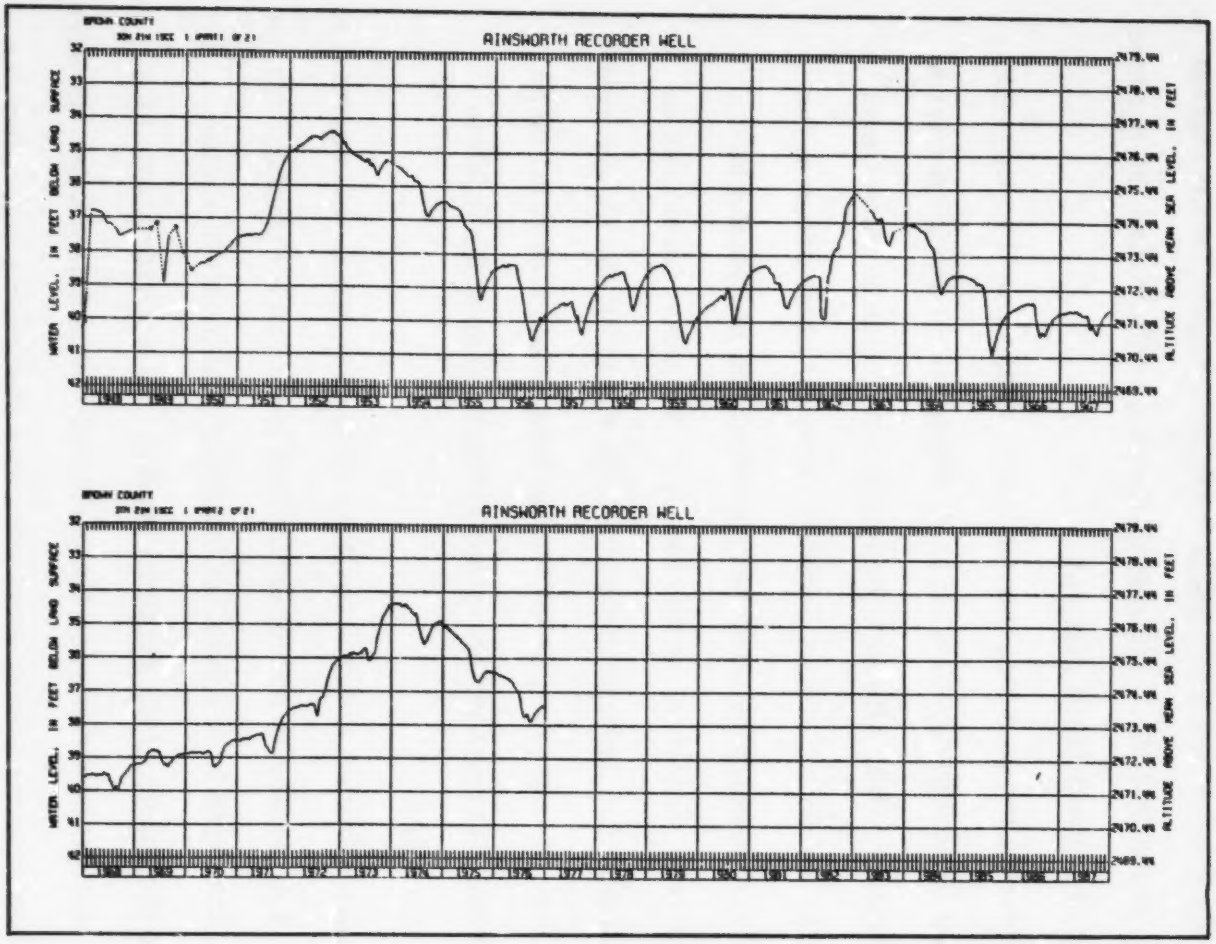


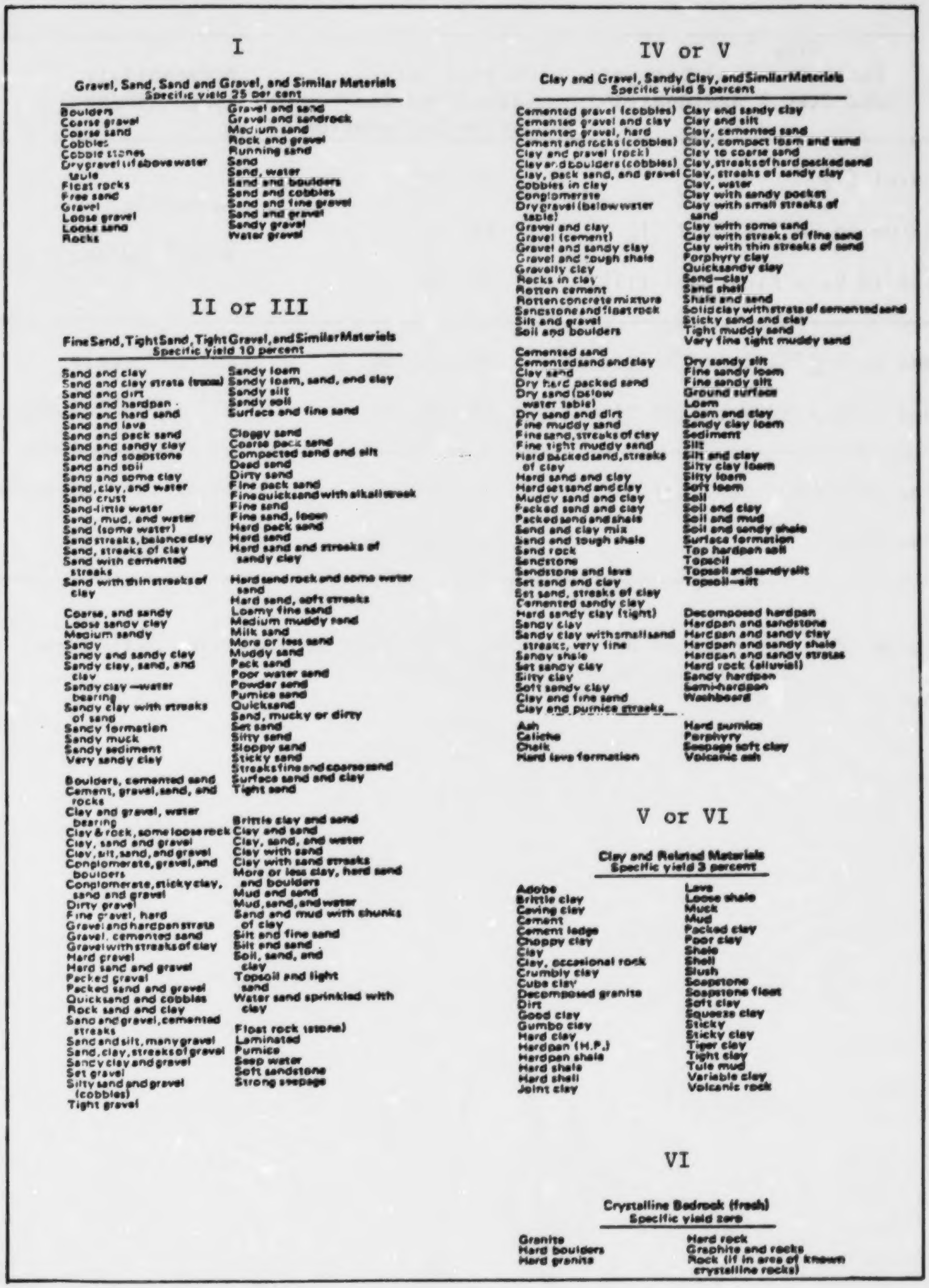
Figure 5. Well hydrograph of the Ainsworth, Nebraska, water supply well showing annual and longer term ground water level fluctuations (from Ellis and Pederson, 1977, p. 67).

net hydrostatic head of the confined aquifer. With the reductions of head which can be experienced (as in many irrigated areas of the country), confined aquifers may become vulnerable to contamination from surface sources through over pumping.

## Step 1, Part B, Determination of the earth material category for Step 1

The type of earth material must be identified in order to complete Step 1. Table I contains an ordinal ranking of the general categories of earth materials based upon permeability, secondarily upon sorption character. The inclusion of sorption is based on the general relationships between grain size/surface area and permeability/sorption. Grain size (or pore size) is proportional to permeability and inversely proportional to surface area which is an important factor in sorption mechanisms. As grain size is inversely proportional to sorption capacity, sorption capacity is inversely proportional to permeability. Thus, going from left to right across the earth material categories in Table I, permeability decreases while sorption generally tends to increase. The categories take into account whether the permeability of the material is primary (properties existing at the time of formation such as the pore spaces) or secondary (properties of the material imposed upon it sometime after formation such as joints, fractures, faults and solution channels). Secondary permeability is usually much greater than primary permeability due to the larger pathways. This distinction is very important in the categorization of earth materials as the presence of secondary permeability increases the flow of water and decreases attenuation. Fractures, joints, and faults are caused by earth movement and generally become closed and tighter with depth (generally within a hundred meters) because of increased pressures and decreased weathering effects. Faults often have an associated zone of crushed rock (fault breccia) which may be highly permeable.

The classification of the earth material should follow the guidelines of Table I and of Figures 6 and 7 which supply further assistance in the classification. Figure 6 gives a fairly comprehensive list of driller's terms found in driller's logs and the equivalent classification for Table I. Some groups of terms are assigned to more than one category, in which case the investigator must make a judgement. In Figure 7, the equivalent Unified Soil Classification System codes are shown.



I

Gravel, Sand, Sand and Gravel, and Similar Materials
Specific yield 25 per cent

Boulders
Coarse gravel
Coarse sand
Cobbles
Cobble stones
Drygravel (if abovewater table)
Float rocks
Free sand
Gravel
Loose gravel
Loose sand
Rocks

Gravel and sand
Gravel and sandrock
Medium sand
Rock and gravel
Running sand
Sand
Sand, water
Sand and boulders
Sand and cobbles
Sand and fine gravel
Sand and gravel
Sandy gravel
Water gravel

II or III

Fine Sand, Tight Sand, Tight Gravel, and Similar Materials
Specific yield 10 percent

Sand and clay
Sand and clay strata (traces)
Sand and dirt
Sand and hardpan
Sand and hard sand
Sand and lava
Sand and pack sand
Sand and sandy clay
Sand and soapstone
Sand and soil
Sand and some clay
Sand, clay, and water
Sand crust
Sand-little water
Sand, mud, and water
Sand (some water)
Sand streaks, balance clay
Sand, streaks of clay
Sand with cemented streaks
Sand with thin streaks of clay

Coarse, and sandy
Loose sandy clay
Medium sandy
Sandy
Sandy and sandy clay
Sandy clay, sand, and clay
Sandy clay—water bearing
Sandy clay with streaks of sand
Sandy formation
Sandy muck
Sandy sediment
Very sandy clay

Boulders, cemented sand
Cement, gravel, sand, and rocks
Clay and gravel, water bearing
Clay & rock, some loose rock
Clay, sand and gravel
Clay, silt, sand, and gravel
Conglomerate, gravel, and boulders
Conglomerate, sticky clay, sand and gravel
Dirty gravel
Fine gravel, hard
Gravel and hardpan strata
Gravel, cemented sand
Gravel with streaks of clay
Hard gravel
Hard sand and gravel
Packed gravel
Packed sand and gravel
Quicksand and cobbles
Rock sand and clay
Sand and gravel, cemented streaks
Sand and silt, many gravel
Sand, clay, streaks of gravel
Sandy clay and gravel
Set gravel
Silty sand and gravel (cobbles)
Tight gravel

Sandy loam
Sandy loam, sand, and clay
Sandy silt
Sandy soil
Surface and fine sand

Cloggy sand
Coarse pack sand
Compacted sand and silt
Dead sand
Dirty sand
Fine pack sand
Fine quicksand with alkali streak
Fine sand
Fine sand, loose
Hard pack sand
Hard sand
Hard sand and streaks of sandy clay

Hard sand rock and some water sand
Hard sand, soft streaks
Loamy fine sand
Medium muddy sand
Milk sand
More or less sand
Muddy sand
Pack sand
Poor water sand
Powder sand
Pumice sand
Quicksand
Sand, mucky or dirty
Set sand
Silty sand
Sloppy sand
Sticky sand
Streaks fine and coarse sand
Surface sand and clay
Tight sand

Brittle clay and sand
Clay and sand
Clay, sand, and water
Clay with sand
Clay with sand streaks
More or less clay, hard sand and boulders
Mud and sand
Mud, sand, and water
Sand and mud with chunks of clay
Silt and fine sand
Silt and sand
Soil, sand, and clay
Topsoil and light sand
Water sand sprinkled with clay

Float rock (stone)
Laminated
Pumice
Seep water
Soft sandstone
Strong seepage

IV or V

Clay and Gravel, Sandy Clay, and Similar Materials
Specific yield 5 percent

Cemented gravel (cobbles)
Cemented gravel and clay
Cemented gravel, hard
Cement and rocks (cobbles)
Clay and gravel (rock)
Clay and boulders (cobbles)
Clay, pack sand, and gravel
Cobbles in clay
Conglomerate
Dry gravel (below water table)
Gravel and clay
Gravel (cement)
Gravel and sandy clay
Gravel and tough shale
Gravelly clay
Rocks in clay
Rotten cement
Rotten concrete mixture
Sandstone and float rock
Silt and gravel
Soil and boulders

Cemented sand
Cemented sand and clay
Clay sand
Dry hard packed sand
Dry sand (below water table)
Dry sand and dirt
Fine muddy sand
Fine sand, streaks of clay
Fine tight muddy sand
Hard packed sand, streaks of clay
Hard sand and clay
Hard set sand and clay
Muddy sand and clay
Packed sand and clay
Packed sand and shale
Sand and clay mix
Sand and tough shale
Sand rock
Sandstone
Sandstone and lava
Set sand and clay
Set sand, streaks of clay
Cemented sandy clay
Hard sandy clay (tight)
Sandy clay
Sandy clay with small sand streaks, very fine
Sandy shale
Set sandy clay
Silty clay
Soft sandy clay
Clay and fine sand
Clay and pumice streaks

Ash
Caliche
Chalk
Hard lava formation

Clay and sandy clay
Clay and silt
Clay, cemented sand
Clay, compact loam and sand
Clay to coarse sand
Clay, streaks of hard packed sand
Clay, streaks of sandy clay
Clay, water
Clay with sandy pocket
Clay with small streaks of sand
Clay with some sand
Clay with streaks of fine sand
Clay with thin streaks of sand
Porphyry clay
Quicksandy clay
Sand—clay
Sand shell
Shale and sand
Solid clay with strata of cemented sand
Sticky sand and clay
Tight muddy sand
Very fine tight muddy sand

Dry sandy silt
Fine sandy loam
Fine sandy silt
Ground surface
Loam
Loam and clay
Sandy clay loam
Sediment
Silt
Silt and clay
Silty clay loam
Silty loam
Soft loam
Soil
Soil and clay
Soil and mud
Soil and sandy shale
Surface formation
Top hardpan soil
Topsoil
Topsoil and sandy silt
Topsoil—silt

Decomposed hardpan
Hardpan and sandstone
Hardpan and sandy clay
Hardpan and sandy shale
Hardpan and sandy stratas
Hard rock (alluvial)
Sandy hardpan
Semi-hardpan
Washboard

Hard pumice
Porphyry
Seepage soft clay
Volcanic ash

V or VI

Clay and Related Materials
Specific yield 3 percent

Adobe
Brittle clay
Caving clay
Cement
Cement ledge
Choppy clay
Clay
Clay, occasional rock
Crumbly clay
Cube clay
Decomposed granite
Dirt
Good clay
Gumbo clay
Hard clay
Hardpan (H.P.)
Hardpan shale
Hard shale
Hard shell
Joint clay

Lava
Loose shale
Muck
Mud
Packed clay
Poor clay
Shale
Shell
Slush
Soapstone
Soapstone float
Soft clay
Squeeze clay
Sticky
Sticky clay
Tiger clay
Tight clay
Tule mud
Variable clay
Volcanic rock

VI

Crystalline Bedrock (fresh)
Specific yield zero

Granite
Hard boulders
Hard granite

Hard rock
Graphite and rocks
Rock (if in area of known crystalline rocks)

Figure 6. Common driller's terms used in estimating specific yield (from Todd, 1970, p. 205) and the equivalent evaluation system earth material categories.

| Step 1 Earth Material Category (and Step 1 Designation) | Unified Soil Classification System Designation | Permeability Range (cm/sec) |
|---|---|---|
| Gravel (I) | GW, GP | Permeable<br>$> 10^{-4}$ cm/sec |
| Medium to Coarse Sand (I) | SW, SP | |
| Fine to Very Fine Sand (II) | SW, SP | |
| Sand with $\leq$15% Clay, Silt (III) | GM, SM, SC | Semi-permeable<br>$10^{-2}$ to $10^{-6}$ cm/sec |
| Sand with $>$15% but $\leq$50% Clay (IV) | GM, SM, ML | |
| Clay with $<$50% Sand (V) | OL, MH | Relatively impermeable<br>$< 10^{-6}$ cm/sec |
| Clay (VI) | CL, CH, OH | |

Figure 7. Earth material categories and their approximate Unified Soil Classification System equivalents.

The geologic conditions beneath the site can be a very complex layering of clays, sands and gravels or consolidated sedimentary rocks such as sandstone, limestone and shale. In these layered situations the rating may be accomplished by considering the probable hydrology of the system. Where the different layers have similar hydrologic properties, the layers may be considered a single hydrologic unit for rating purposes. Where contrasting layers are encountered, best judgement must be exercised in rating the site. For example, if an impermeable shale overlies permeable sandstone rate only the thickness of shale. The investigator must be cautioned, however, that in rating a case where hydrologically unlike layers alternate, the waste is more likely to move through the more permeable zones and avoid the impermeable layers. As an example, a sand containing clay lenses should be rated as if only sand were present (See Figure 8). Similarly, where secondary permeability is present (i. e. fractures, joints and faults) the major path of waste movement is through the large conduits of secondary permeability rather than the interstices of primary permeability. This results in a short circuit of any attenuation capability present in the material. In such cases, the earth material would be rated as the more permeable categories.

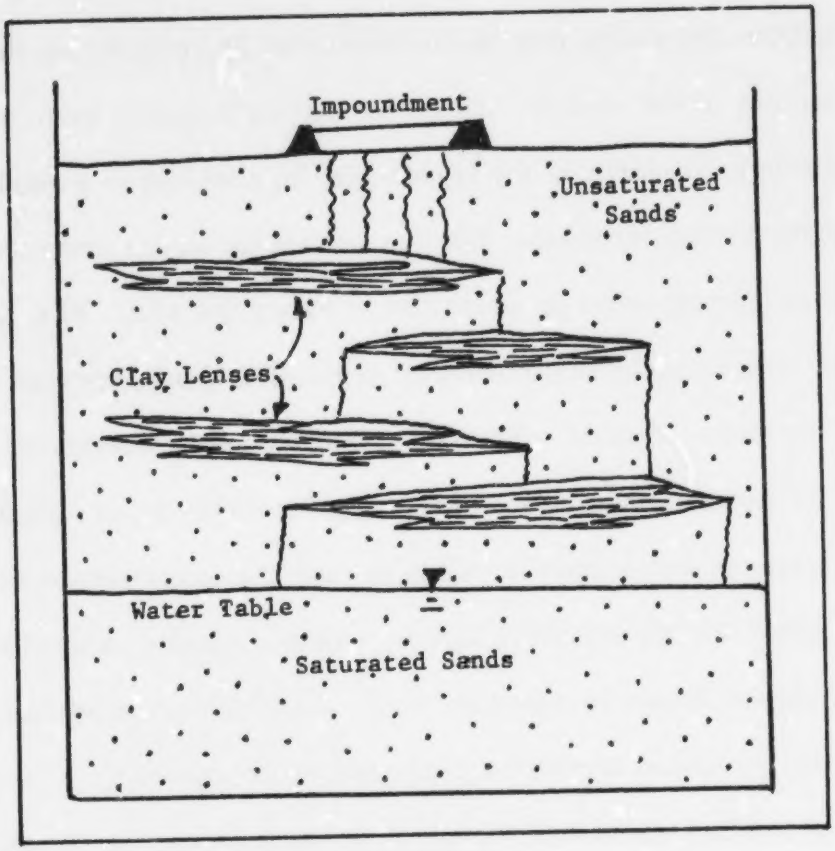

Impoundment
Unsaturated Sands
Clay Lenses
Water Table
Saturated Sands

Figure 8. Hypothetical flow paths of waste fluids seeping from a surface impoundment through unsaturated sands containing clay lenses.

## Step 1, Part C, The Scoring of Step 1.

After the thickness of the unsaturated zone and the type of earth material in the unsaturated zone have been determined, refer to the Step 1 matrix (in Table 1) and record the appropriate score for the particular values of thickness and material.

## Sources of information for completing Step 1.

Many data sources exist for the depth to the water table and the geologic material beneath a site. The site may have specific data available from State files if the site is permitted. The owner/operator may have data on shallow bedrock and soils available from borings or trenches made for the impoundment or nearby building foundations. Nearby water wells may provide data on the geology and ground-water levels, and adjacent road cuts can provide additional information on the subsurface.

General information is available from State agency reports such as the State geological survey, State departments of transportation soil borings, water resources agencies or universities with departments concerned with geology and ground-water resources. The United States Geological Survey also publishes reports and maintains files on ground water occurrence in each State. The U.S. Department of Agriculture, Soil Conservation Service, publishes county soils reports and maps with information on local soil profiles and bedrock, depth to the water table and depth to unweathered bedrock or parent material of the soil.

### Example for determining the score for Step 1.

To score a site for Step 1, information is needed on: 1) the depth to the saturated zone and 2) the earth material of the unsaturated zone. The following example illustrates the method of scoring a site and will be utilized in all steps of the evaluation system.

A poultry processing plant, located in the Appalachian Valley and Ridge Province of a Mid-Atlantic State, operates a two acre waste treatment lagoon (about 8000 m ) for disposal of poultry processing waste water. The waste treatment lagoon is shown in the site plan of Figure 9; Figure 10 gives the site location in relation to local topography.

**Example Step 1, Part A.** Determine the depth to the water table to establish the thickness of the unsaturated zone. In this example the depth to the water table may be obtained from the driller's log of the plant water well. Figure 11 shows the driller's report which indicates that the depth to the static water table is 33 feet (about 10 meters). This static water table level is not the seasonal high water table at this site. The seasonal high water table would be expected to occur around 25 feet (7.5 meters).

The depth to the water table could also be estimated by studying the topographic map in Figure 10 if no well data was available. The elevation of the lagoon bottom is estimated to be about 1020 feet (311 meters) Mean Sea Level as the site is located between two 1020 foot contours. The river is about 100 feet (30 meters) to the west and, in the humid eastern climate, the water table can be assumed to be the river level at the river. Since the lagoon is close to the river, the water table is estimated to be about the same elevation as the river, i.e., 990 feet (302 meters). This is determined by noting that the 980 foot (299 meters) elevation crosses the river about 1 mile (1.6 kilometers) downstream and the 1000 foot (305 meters) elevation crosses about 1 mile upstream. Interpolation between 980 and 1000 gives a river elevation of 990 feet. By estimating the lagoon elevation (1020 feet) and adjacent

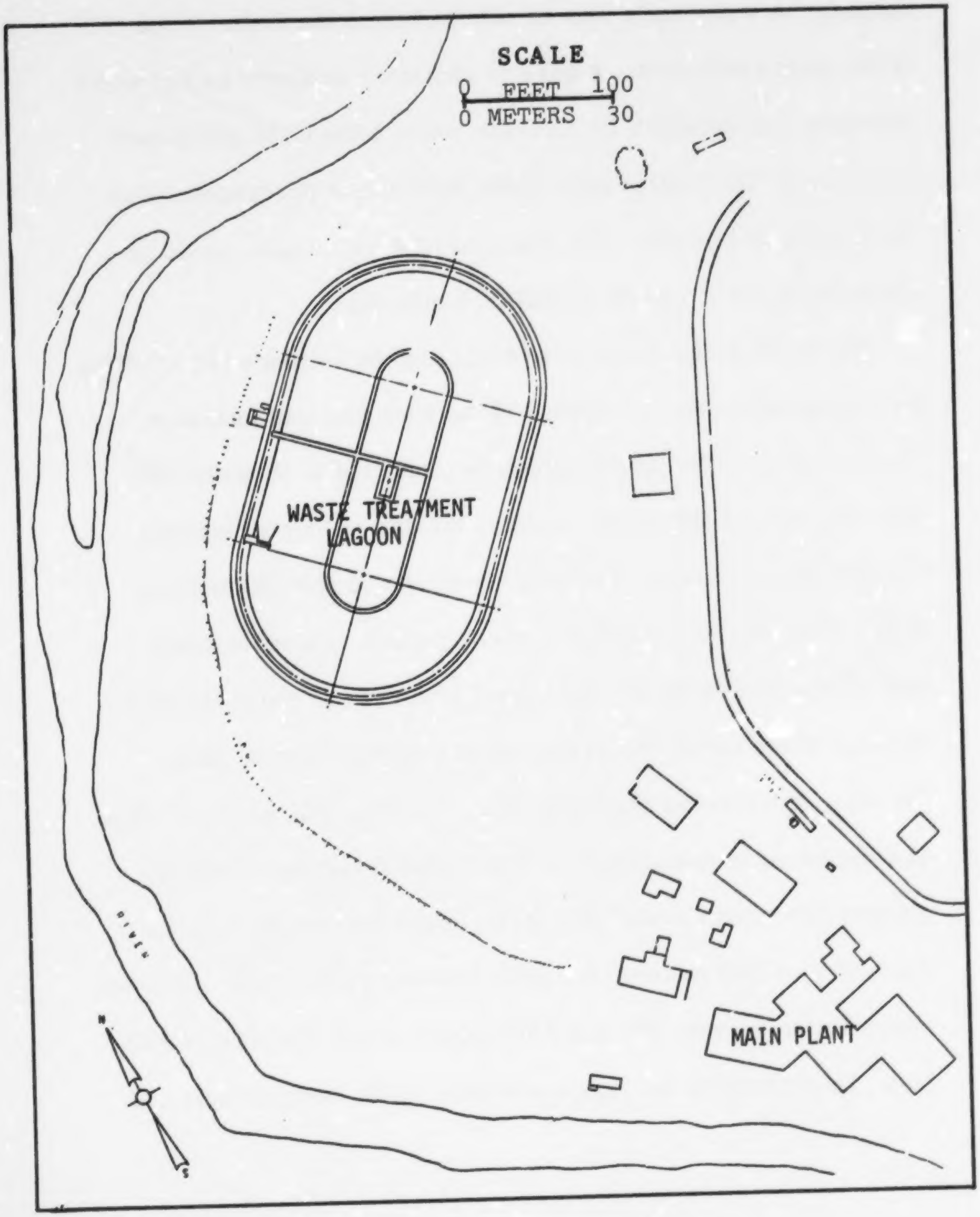

SCALE
0 FEET 100
0 METERS 30
WASTE TREATMENT LAGOON
MAIN PLANT
N
S

Figure 9. Poultry Processing Plant site plan.

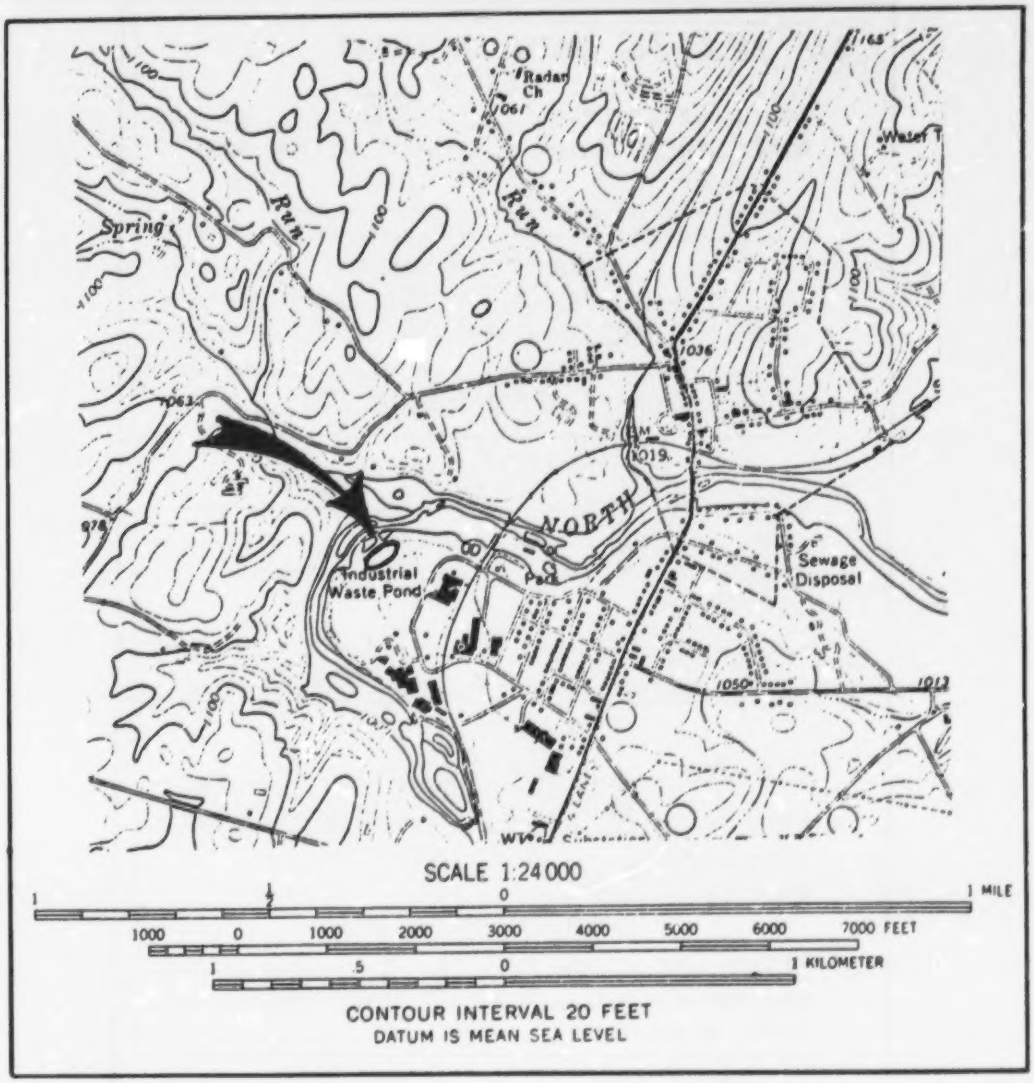
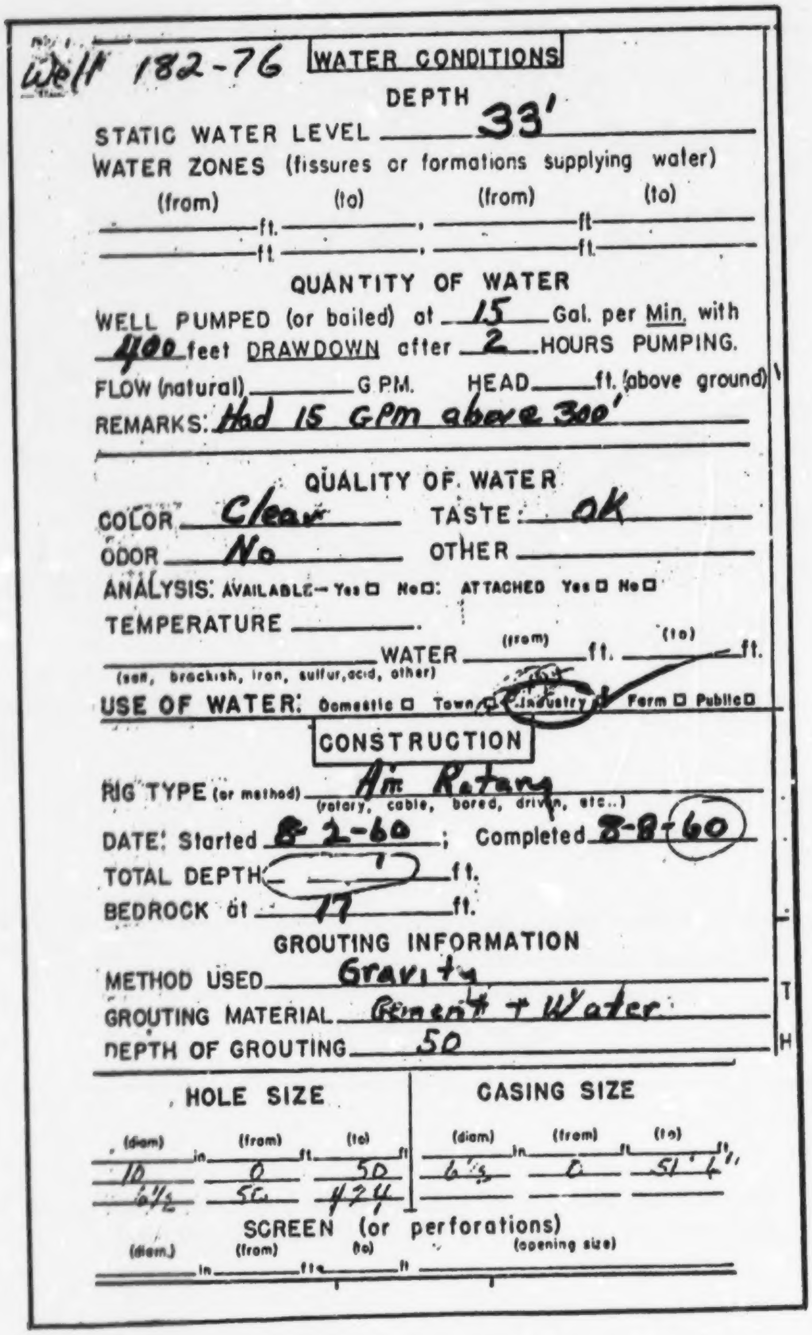

Radar Ch
1061
Spring
Run
Run
1036
1063
1019
NORTH
Industrial Waste Pond
Sewage Disposal
1050
1013
SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Figure 10. Portion of the 7.5 minute quadrangle topographic map of the Poultry Processing Plant (Marked by arrow).



Well 182-76

WATER CONDITIONS

STATIC WATER LEVEL DEPTH 33'

WATER ZONES (fissures or formations supplying water)

(from) ______ ft. (to) ______, (from) ______ ft. (to) ______

______ ft. ______, ______ ft. ______

QUANTITY OF WATER

WELL PUMPED (or bailed) at 15 Gal. per Min. with 400 feet DRAWDOWN after 2 HOURS PUMPING.

FLOW (natural) ______ G.P.M. HEAD ______ ft. (above ground)

REMARKS: Had 15 GPm above 300'

QUALITY OF WATER

COLOR Clear TASTE: ok

ODOR No OTHER ______

ANALYSIS: AVAILABLE— Yes ☐ No ☐: ATTACHED Yes ☐ No ☐

TEMPERATURE ______.

______ WATER (from) ______ ft. (to) ______ ft.

(salt, brackish, iron, sulfur, acid, other)

USE OF WATER: Domestic ☐ Town ☐ Industry ☑ Farm ☐ Public ☐

CONSTRUCTION

RIG TYPE (or method) Air Rotary

(rotary, cable, bored, driven, etc..)

DATE: Started 8-2-60; Completed 8-8-60

TOTAL DEPTH ______ ft.

BEDROCK at 77 ft.

GROUTING INFORMATION

METHOD USED Gravity

GROUTING MATERIAL Cement + Water

DEPTH OF GROUTING 50

| HOLE SIZE (diam) in. | (from) ft. | (to) ft. | CASING SIZE (diam) in. | (from) ft. | (to) ft. |
|---|---|---|---|---|---|
| 10 | 0 | 50 | 6⅝ | 0 | 51'4" |
| 6½ | 50 | 474 | | | |

SCREEN (or perforations)

(diam.) ______ in. (from) ______ ft. (to) ______ ft. (opening size) ______

Figure 11. Portion of the driller's report on the water supply well drilled at the Poultry Processing Plant showing the static ground-water level.

river elevations (990 feet), the water table depth is estimated at 30 feet (about 9 meters). This estimate is fairly close to the measured static water level in the well. This method of estimating ground-water levels is useful only for perennial streams and is not reliable in the arid western United States where streams are intermittent. In such cases the ground-water level is often deeper than the stream bed and may have no relationship to the stream level or topography.

Example Step 1, Part B. The second part of completing Step 1 is to estimate the composition of the earth material of the unsaturated zone. For the Poultry Processing Plant, there is a substantial amount of data available from a county geologic report, the driller's report for the water well at the site and, several test borings conducted at the lagoon site. Figure 12 and 13 show the surface bedrock configuration and the structural cross-section of the area. The bedrock at the site is the Edinburg Formation composed of shale and limestone layers tilted at about 70 degrees to the west. The Driller's report containing the well log (Figure 14) indicates that about 16 feet (about 5 meters) of unconsolidated clay and gravel overlie a considerable thickness of variable limestone down to 424 feet (129 meters).

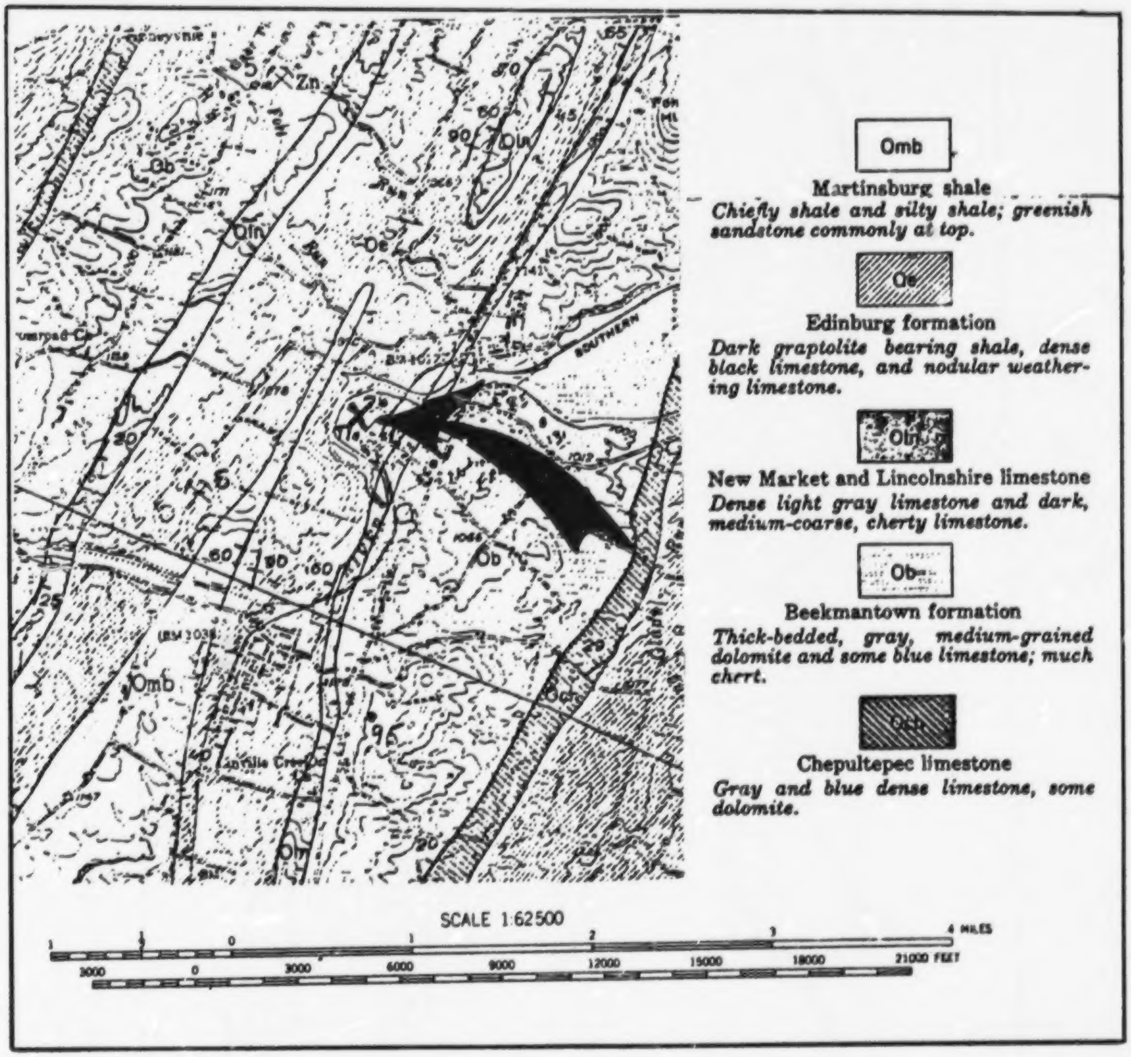
The logs of the test borings shown in Figures 15 indicate a quite variable thickness of sand and gravel (from 12 to 60 feet, or 3 to 18 meters) above limestone. It would be expected in this area of steeply tilted limestone and shale layers to have a rough, variable bedrock surface as a result of differential weathering.

Example, Step 1, Part C. After determining the thickness of the unsaturated zone (7.5 meters) and the type of earth material in the unsaturated zone, the Step 1 score can be determined from the Step 1 matrix in Table I for the following parameters:

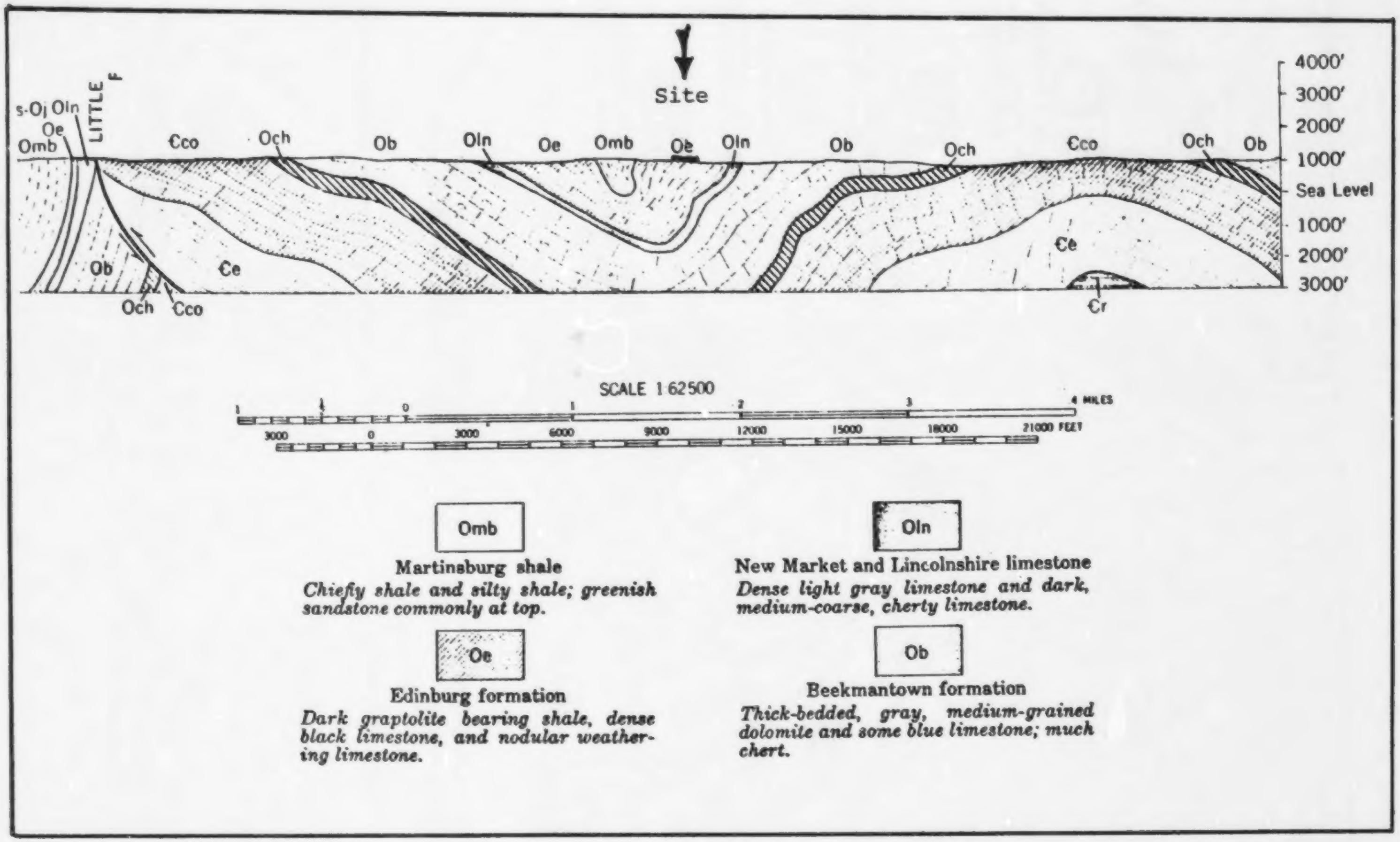
Thickness of the unsaturated zone = 7.5 meters

Material of the unsaturated zone = 3 meters of sand and gravel
4.5 meters of limestone

As the sand, gravel and limestone are of similar hydrologic character and in the same earth material category of Step 1, their thickness can be combined so that the Step 1 score would be determined for 7.5 meters of category "I" material rated at 9C. (The presence of a liner would be noted by recording the appropriate code in the reporting form.)


Omb
Martinsburg shale
Chiefly shale and silty shale; greenish sandstone commonly at top.
Oe
Edinburg formation
Dark graptolite bearing shale, dense black limestone, and nodular weathering limestone.
Oln
New Market and Lincolnshire limestone
Dense light gray limestone and dark, medium-coarse, cherty limestone.
Ob
Beekmantown formation
Thick-bedded, gray, medium-grained dolomite and some blue limestone; much chert.
Och
Chepultepec limestone
Gray and blue dense limestone, some dolomite.
SCALE 1:62500
1
0
1
2
3
4 MILES
3000
0
3000
6000
9000
12000
15000
18000
21000 FEET
Zn
Omb
Ob
Oln
Oe
Och
X
SOUTHERN
RIVER
Linville Creek
BM 1036

Fugure 12. Portion of the geologic map from the County Geologic Report containing the location of the Poultry Processing Plant (marked by an X and an arrow).



Site
s-Oj Oln
Oe
Omb
LITTLE F
Cco
Och
Ob
Oln
Oe
Omb
Oe
Oln
Ob
Och
Cco
Och
Ob
Ob
Och
Cco
Ce
Ce
Cr
4000′
3000′
2000′
1000′
Sea Level
1000′
2000′
3000′
SCALE 1:62500
1
0
1
2
3
4 MILES
3000
0
3000
6000
9000
12000
15000
18000
21000 FEET
Omb
Oln
Oe
Ob

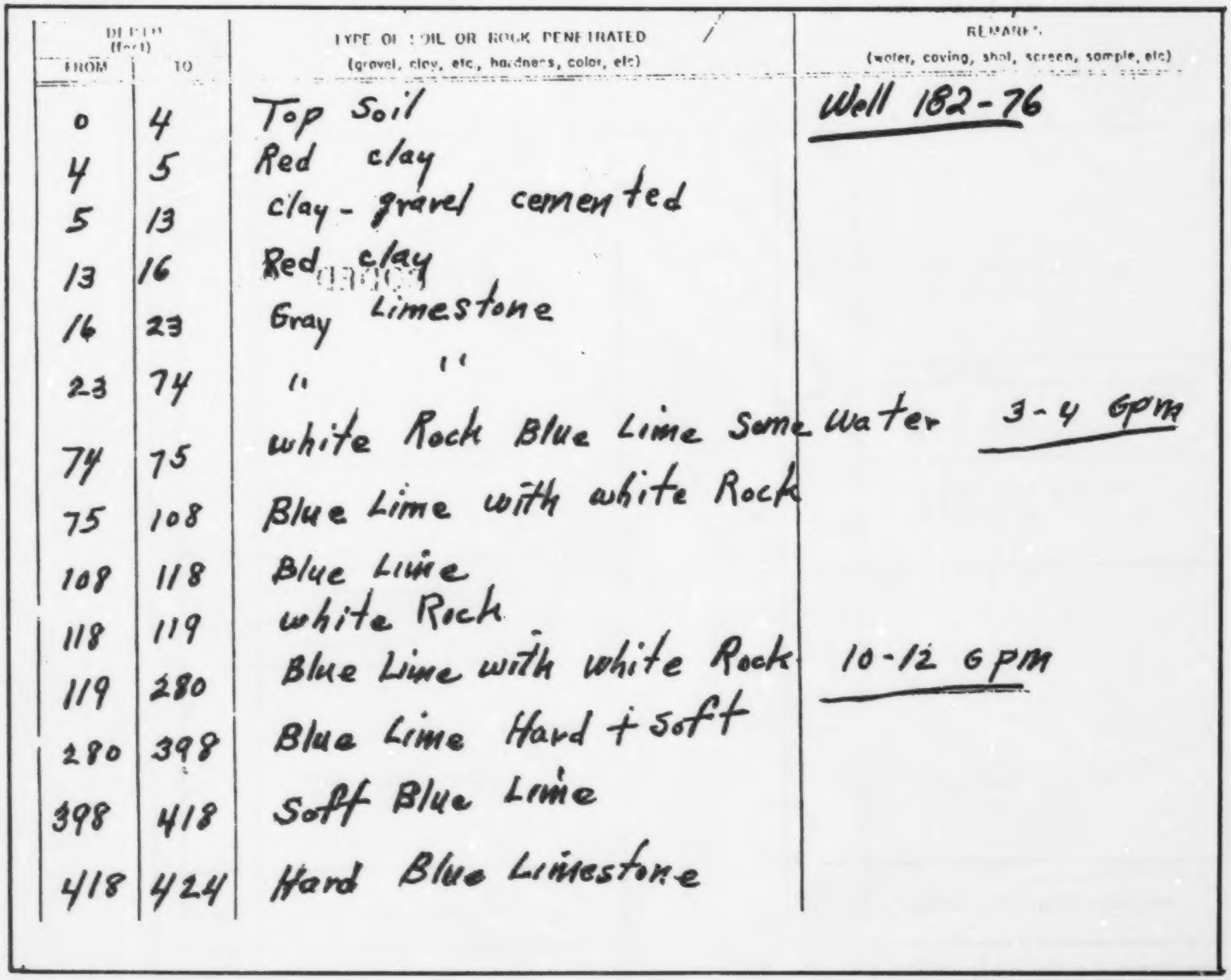
**Martinsburg shale**
*Chiefly shale and silty shale; greenish sandstone commonly at top.*

**Edinburg formation**
*Dark graptolite bearing shale, dense black limestone, and nodular weathering limestone.*

**New Market and Lincolnshire limestone**
*Dense light gray limestone and dark, medium-coarse, cherty limestone.*

**Beekmantown formation**
*Thick-bedded, gray, medium-grained dolomite and some blue limestone; much chert.*

Figure 13. Portion of a geologic cross-section from the County Geologic Report depicting the general subsurface geologic structure around the Poultry Processing Plant (marked by the arrow).



| DEPTH (feet) FROM | TO | TYPE OF SOIL OR ROCK PENETRATED (gravel, clay, etc., hardness, color, etc) | REMARKS (water, caving, shot, screen, sample, etc) |
|---|---|---|---|
| 0 | 4 | Top Soil | Well 182-76 |
| 4 | 5 | Red clay | |
| 5 | 13 | clay - gravel cemented | |
| 13 | 16 | Red clay | |
| 16 | 23 | Gray Limestone | |
| 23 | 74 | " " | |
| 74 | 75 | white Rock Blue Lime | Some Water 3-4 GPM |
| 75 | 108 | Blue Lime with white Rock | |
| 108 | 118 | Blue Lime | |
| 118 | 119 | white Rock | |
| 119 | 280 | Blue Lime with white Rock | 10-12 GPM |
| 280 | 398 | Blue Lime Hard + soft | |
| 398 | 418 | Soft Blue Lime | |
| 418 | 424 | Hard Blue Limestone | |

Figure 14. Portion of the driller's report on the water supply well drilled at the Poultry Processing Plant showing the well log.

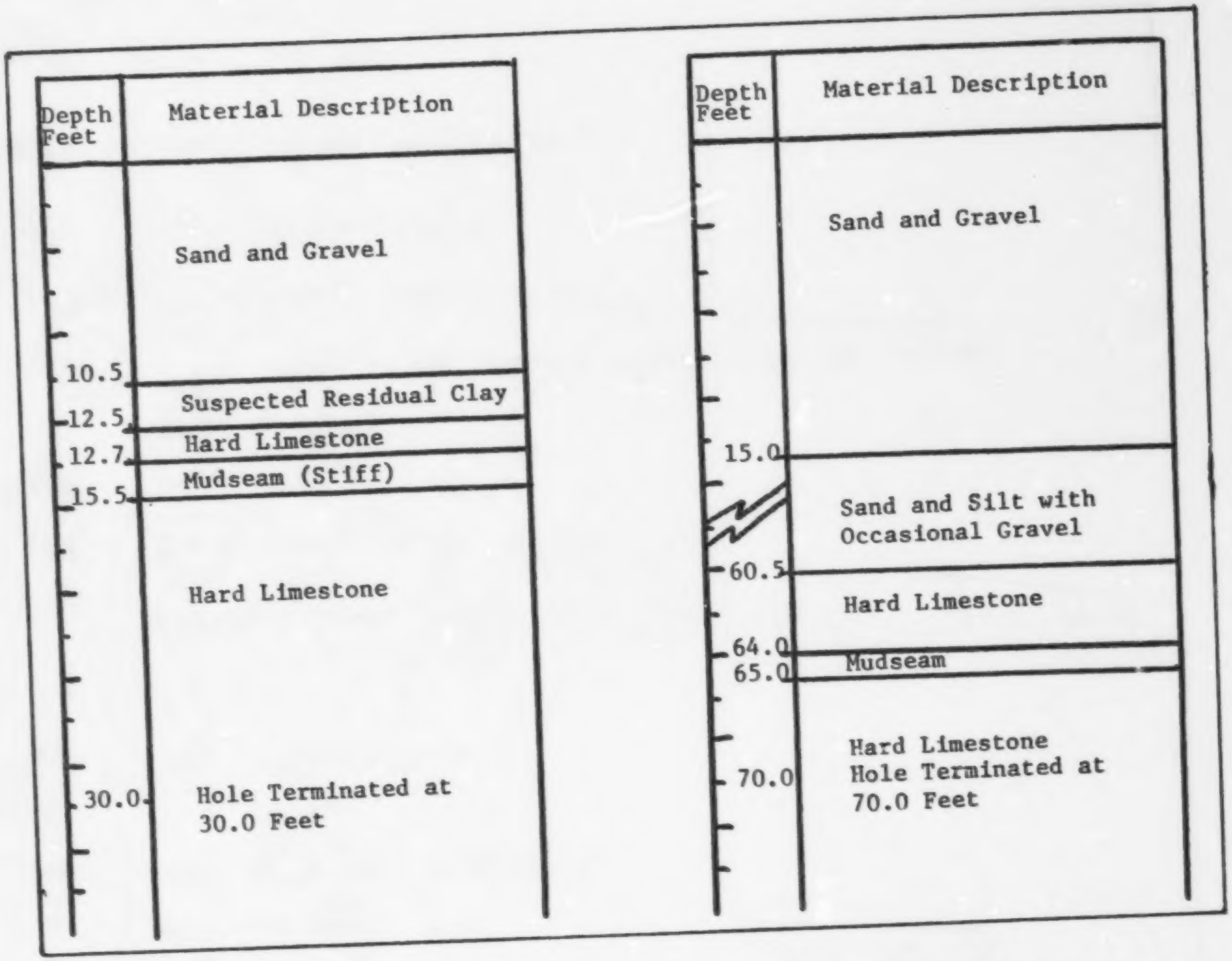

Depth Feet
Material Description
Sand and Gravel
10.5
Suspected Residual Clay
12.5
Hard Limestone
12.7
Mudseam (Stiff)
15.5
Hard Limestone
30.0
Hole Terminated at 30.0 Feet
Depth Feet
Material Description
Sand and Gravel
15.0
Sand and Silt with Occasional Gravel
60.5
Hard Limestone
64.0
Mudseam
65.0
Hard Limestone
70.0
Hole Terminated at 70.0 Feet

Figure 15. Driller's logs of test borings beneath the waste treatment lagoon at the Poultry Processing Plant.

## STEP 2

## GUIDANCE FOR RATING GROUND WATER AVAILABILITY

### Determining the ground-water availability ranking.

The ability of the aquifer to transmit ground water depends upon the permeability and saturated thickness of the aquifer. Step 2 provides the guidance to determine the ground-water availability rating of the aquifer. Since this evaluation system is a first-round approximation, the ground-water availability rating is not exact, but an approximation. The categories of earth material which make up the saturated zone are the same categories as used in Step 1 but have been combined into good, fair and poor aquifer material categories (Table II).

Estimate the aquifer's saturated thickness (in meters) and the type of earth material in the saturated zone as done for Step 1. Choose the appropriate ranking in the matrix of Step 2 (Table II) from the respective saturated thickness and earth material category. The letter accompanying the ranking is for the purpose of identifying what the ranking's derivation is if, at sometime in the future, there is reason to verify the number.

### Sources of information for completing Step 2.

Sources of information in determining the parameters of Step 2 are similar to those of Step 1.

## TABLE II

Step 2. Rating of the Ground Water Availability

| | Earth Material Category | I | II | III |
|---|---|---|---|---|
| GUIDELINES FOR DETERMINING CATEGORY | Unconsolidated Rock | Gravel or sand | Sand with $\leq 50\%$ clay | Clay with $< 50\%$ sand |
| | Consolidated Rock | Cavernous or Fractured Rock, Poorly Cemented Sandstone, Fault Zones | Moderately to Well Cemented Sandstone, Fractured Shale | Siltstone, Unfractured Shale and other Impervious Rock |
| | Representative Permeability<br>in gpd/ft$^2$<br>in cm/sec | <br>$> 2$<br>$> 10^{-4}$ | <br>$0.02 - 2$<br>$10^{-6} - 10^{-4}$ | <br>$< 0.02$<br>$< 10^{-6}$ |
| | RATING MATRIX | | | |
| | Thickness of Saturated Zone (Meters) $\geq 30$ | 6A | 4C | 2E |
| | 3-30 | 5A | 3C | 1E |
| | $\leq 3$ | 3A | 1C | 0E |

Example, Step 2.

The type of earth material of the saturated zone can be determined from the county geologic map and cross-section (Figures 11 and 12) and the driller's log of Figure 13. Generally, the material down to greater than 400 feet (122 meters) below the surface is limestone with shale interbeds. From the drillers' report of the pump test (shown in Figure 10) the water supply well near the surface impoundment had 400 feet of drawdown at 15 gpm (57 liters per minute) after 2 hours pumping. From this data the limestone is very tight with little permeability and very little development of open fractures. The category in Step 2 for rating this material would be category II as the saturated zone is capable of producing water but only at moderate to low quantites. From the above sources of information the thickness of the saturated zone is estimated to be several hundred feet. The score for the ground-water availability ranking would be determined for earth material category II and greater than 30 meters thickness, i.e., the Step 2 ranking is "4C."

# STEP 3

## GUIDANCE FOR RATING THE GROUND-WATER QUALITY

Ground-water quality is a determinant of the ultimate usefulness of the ground water. Waste disposal sites situated in an area of poor quality ground water unsuitable as a drinking water supply would not present the same degree of pollution potential to ground water as the same site situated in an area having very good quality ground water. Step 3 (Table III) is used to determine the ranking of the aquifer's ground-water quality. The ranking is based upon the criteria that has been set forth in the proposed Underground Injection Control Regulations (40 CFR Part 146) of the Safe Drinking Water Act of 1974 (P. L. 93-523). The descriptions are to be used as basic guidelines to assist the investigator in arriving at the appropriate rating of ground-water quality. Consideration of only the background water quality of the aquifer is intended.

### Determine the Aquifer Quality Ranking

Determine the total dissolved solids content of the ground water and apply it to the appropriate rating in Step 3, Table III. If the ground water is presently a drinking water supply, the ranking would be a "5" regardless of its total dissolved solids content.

Table III

Step 3. Rating the Ground-Water Quality

| Rating | Quality |
|---|---|
| 5 | ≤ 500 mg/l TDS or a current drinking water source |
| 4 | > 500 - ≤ 1000 mg/l TDS |
| 3 | > 1000 - ≤ 3000 mg/l TDS |
| 2 | > 3000 - ≤ 10,000 mg/l TDS |
| 1 | > 10,000 mg/l TDS |
| 0 | No ground water present |

## Sources of information for completing Step 3 .

Ground-water quality data for the determination of the Step 3 rating may be obtained from several sources. If the aquifer is presently used by individuals or communities, no further documentation is required. If industries or agriculture use the ground water, but not currently for human consumption, further quality data may be required for the rating. Many State agencies (i. e., geological surveys, health departments, water boards or commissions and State engineers) and the U. S. Geological Survey have considerable water quality data on file, in published reports and as maps outlining the ground-water quality in the States by aquifer.

## Example, Step 3.

The quality of the ground water beneath the Poultry Processing Plant site would be rated "5" since the aquifer does supply drinking water, and in addition based upon driller's report, general State files and published reports, the aquifer has an overall good quality with very low total dissolved solids.

## STEP 4

## GUIDANCE FOR RATING THE WASTE HAZARD POTENTIAL

Contaminants that may enter ground water have been evaluated by their potential for causing harm to human health (Hazard Potential). The hazard potential rankings for contaminants range from 1 to 9 with 1 being least hazardous and 9 being most hazardous.

Contaminants and their hazard potential rankings are classified in two ways: (1) by contaminant source (Table IV), and (2) by contaminant type (Table V). Standard Industrial Classification (SIC) numbers are used to classify sources. Common sources and types of contaminants and their hazard potential ranges are illustrated in Figure 16.

There are many variables that influence a substance as it enters the ground-water environment such that its true hazard potential as a ground-water contaminant is not likely to be the same as its apparent hazard potential. Most such variables tend to reduce hazard potentials. The hazard potential rankings considered the following factors and their interactions.

TOXICITY - The ability of a substance to produce harm in or on the body of living organisms is extremely important in ranking the hazard potential of that substance. While some substances are highly toxic they may possess low mobility and thus be assigned a lower hazard potential ranking than a less toxic but highly mobile substance.

# TABLE IV

## CONTAMINANT HAZARD POTENTIAL RANKINGS OF WASTE, CLASSIFIED BY SOURCE FOR STEP 4.

| SIC Number | | Description of Waste Source | Hazard Potential Initial Rating |
|---|---|---|---|
| 01 | | AGRICULTURAL PRODUCTION - CROPS | 1-2 |
| 02 | | AGRICULTURAL PRODUCTION - LIVESTOCK | |
| | 021 | Livestock, except Dairy, Poultry and Animal Specialties | 3<br>(5 for Feedlots) |
| | 024 | Dairy Farms | 4 |
| | 025 | Poultry and Eggs | 4 |
| | 027 | Animal Specialties | 2-4 |
| | 029 | General Farms, Primarily Livestock | 2 |
| 10 | | METAL MINING | |
| | 101 | Iron Ores | 4 |
| | 102 | Copper Ores | 6 |
| | 103 | Lead and Zinc Ores | 5 |
| | 104 | Gold and Silver Ores | 6 |
| | 105 | Bauxite and other Aluminum Ores | 5 |
| | 106 | Ferroalloy Ores Except Vanadium | 5 |
| | 108 | Metal Mining Services | 4 |
| | 1092 | Mercury Ore | 6 |
| | 1094 | Uranium-Radium-Vanadium Ores | 7 |
| | 1099 | Metal Ores not elsewhere classified | 5 |
| 11 | | ANTHRACITE MINING | 7 |
| 12 | | BITUMINOUS COAL AND LIGNITE MINING | 7 |
| 13 | | OIL AND GAS EXTRACTION | |
| | 131 | Crude Petroleum and Natural Gas | 7 |
| | 132 | Natural Gas Liquids | 7 |
| | 1381 | Drilling Oil and Gas Wells | 6 |
| | 1382 | Oil and Gas Field Exploration Services | 1 |
| | 1389 | Oil and Gas Field Services not elsewhere classified | Variable depending on Activity |
| 14 | | MINING AND QUARRYING OF NON-METALLIC MINERALS, EXCEPT FUELS | |
| | 141 | Dimension Store | 2 |
| | 142 | Crushed and Broken Stone, Including Riprap | 2 |
| | 144 | Sand and Gravel | 2 |
| | 145 | Clay, Ceramic, and Refractory Minerals | 2-5 |
| | 147 | Chemical and Fertilizer Mineral Mining | 4-7 |
| | 148 | Nonmetallic Minerals Services | 1-7 |
| | 149 | Miscellaneous Non-metallic Minerals, except Fuels | 2-5 |

(TABLE IV continued)

| SIC Number | | Description of Waste Source | Hazard Potential Initial Rating |
|---|---|---|---|
| 16 | | CONSTRUCTION OTHER THAN BUILDING CONSTRUCTION | |
| | 1629 | Heavy Construction, not elsewhere classified (Dredging, especially in salt water) | 4 |
| 20 | | FOOD AND KINDRED PRODUCTS | |
| | 201 | Meat Products | 3 |
| | 202 | Dairy Products | 2 |
| | 203 | Canned and Preserved Fruits and Vegetables | 4 |
| | 204 | Grain Mill Products | 2 |
| | 205 | Bakery Products | 2 |
| | 206 | Sugar and Confectionery Products | 2 |
| | 207 | Fats and Oils | 3 |
| | 208 | Beverages | 2-5 |
| | 209 | Misc. Food Preparation and Kindred Products | 2 |
| 22 | | TEXTILE MILL PRODUCTS, ALL EXCEPT LISTINGS BELOW | |
| | 223 | Broad Woven Fabric Mills, Wool (including dyeing and finishing) | 6 |
| | 226 | Dying and Finishing Textiles, except Wool Fabrics and Knit Goods | 6 |
| | 2295 | Coated Fabrics, Not Rubberized | 6 |
| 24 | | LUMBER AND WOOD PRODUCTS, EXCEPT FURNITURE | |
| | 241 | Logging Camps and Logging Contractors | 2 |
| | 242 | Sawmills and Planing Mills | 2 |
| | 2435 | Hardwood Veneer and Plywood | 4 |
| | 2436 | Softwood Veneer and Plywood | 4 |
| | 2439 | Structural Wood Members, not elsewhere classified (laminated wood-glue) | 3 |
| | 2491 | Wood Preserving | 5 |
| | 2492 | Particle Board | 4 |
| | 2499 | Wood Products, not elsewhere classified | 2-5 |
| 26 | | PAPER AND ALLIED PRODUCTS | |
| | 261 | Pulp Mills | 6 |
| | 262 | Paper Mills Except Building Paper Mills | 6 |
| | 263 | Paperboard Mills | 6 |

(TABLE IV continued)

| SIC Number | Description of Waste Source | Hazard Potential Initial Rating |
|---|---|---|
| 28 | CHEMICALS AND ALLIED PRODUCTS[1] | |
| 2812 | Alkalies and Chlorine | 7-9 |
| 2813 | Industrial Gases | |
| 2816 | Inorganic Pigments | 3-8 |
| 2819 | Industrial Inorganic Chemicals, not elsewhere classified | 3-9 |
| 2821 | Plastic Materials, Synthetic Resins, and Nonvulcanizable Elastomers | 6-8 |
| 2822 | Synthetic Rubber (Vulcanizable Elastomers) | 6-8 |
| 2823 | Cellulose Man-Made Fibers | 6-8 |
| 2824 | Synthetic Organic Fibers, except Cellulosic | 6-8 |
| 2831 | Biological Products | 6-9 |
| 2833 | Medicinal Chemicals and Botanical Products | 3-8 |
| 2834 | Pharmaceutical Preparations | 6-9 |
| 2841 | Soap and Other Detergents, except specialty cleaners | 4-6 |
| 2842 | Specialty Cleaning, Polishing and Sanitation Preparation | 3-8 |
| 2843 | Surface Active Agents, Finishing Agents, Sulfonated Oils and Assistants | 6-8 |
| 2844 | Perfumes, Cosmetics, and other Toilet Preparations | 3-6 |
| 2851 | Paints, Varnisher, Lacquers, Enamels, and Allied Products | 5-8 |
| 2861 | Gum and Wood Chemicals | 5-8 |
| 2865 | Cyclic (coal tar) Crudes, and Cyclic Intermediates, Dyes and Organic Pigments (Lakes and Toners) | 6-9 |
| 2869 | Industrial Organic Chemicals, not elsewhere listed | 3-9 |

(TABLE IV continued)

| SIC Number | | Description of Waste Source | Hazard Potential Initial Rating |
|---|---|---|---|
| | 2873 | Nitrogenous Fertilizers | 7-8 |
| | 2874 | Phosphatic Fertilizers | 7-8 |
| | 2875 | Fertilizer Mixing Only | 5 |
| | 2879 | Pesticides and Agricultural Chemicals, Not Elsewhere Listed | 5-9 |
| | 2891 | Adhesives and Sealants | 5-8 |
| | 2892 | Explosives | 6-9 |
| | 2893 | Printing Ink | 2-5 |
| | 2895 | Carbon Black | 1-3 |
| | 2899 | Chemicals and Chemical Preparations, not Elsewhere Listed | 3-9 |
| 29 | | PETROLEUM REFINING AND RELATED INDUSTRIES | |
| | 291 | Petroleum Refining | 8 |
| | 295 | Paving and Roofing Materials | 7 |
| | 299 | Misc. Products of Petroleum and Coal | 7 |
| 30 | | RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS | |
| | 301 | Tires and Inner Tubes | 6 |
| | 302 | Rubber and Plastic Footwear | 6 |
| | 303 | Reclaimed Rubber | 6 |
| | 304 | Rubber and Plastics Hose and Belting | 4 |
| | 306 | Fabricated Rubber Products, not Elsewhere Classified | 4 |
| 31 | | LEATHER AND LEATHER PRODUCTS | |
| | 311 | Leather Tanning and Finishing | 8 |
| | | (Remaining Three-Digit Codes) | 1-3 |
| 32 | | STONE, CLAY, GLASS, AND CONCRETE PRODUCTS | |
| | 321 | Flat Glass | 4 |
| | 322 | Glass and Glassware, Pressed or Blown | 4 |
| | 324 | Cement, Hydraulic | 3 |
| | 3274 | Lime | 3 |
| | 3291 | Abrasive Products | 3 |
| | 3292 | Asbestos | 3 |
| | 3293 | Gaskets, Packing, and Sealing Devices | 3 |
| 33 | | PRIMARY METAL INDUSTRIES (EXCEPT AS NOTED BELOW) | 3 |
| | 3312 | Blast Furnaces, Steel Works, and Rolling and Finishing Mills | 6 |
| | 333 | Primary Smelting and Refining of Nonferrous Metals | 7 |

(TABLE IV continued)

| SIC Number | | Description of Waste Source | Hazard Potential Initial Rating |
|---|---|---|---|
| 34 | | FABRICATED METAL PRODUCTS, EXCEPT MACHINERY AND TRANSPORTATION EQUIPMENT (EXCEPT AS NOTED BELOW) | 5 |
| | 347 | Coating, Engraving, and Allied Services | 8 |
| | 3482 | Small Arms Ammunition | 7 |
| | 3483 | Ammunition, Except for Small Arms not Elsewhere Classified | 7 |
| | 3489 | Ordnance and Accessories, not Elsewhere Classified | 7 |
| | 349 | Misc. Fabricated Metal Products | 3-6 |
| 35 | | MACHINERY, EXCEPT ELECTRICAL | 5-7 |
| 36 | | ELECTRICAL AND ELECTRONIC MACHINERY, EQUIPMENT AND SUPPLIES (EXCEPT AS NOTED BELOW) | 5-7 |
| | 3691 | Storage Batteries | 8 |
| | 3692 | Primary Batteries, Dry and Wet | 8 |
| 37 | | TRANSPORTATION EQUIPMENT | 5-8 |
| 38 | | MEASURING, ANALYZING, AND CONTROLLING INSTRUMENTS; PHOTOGRAPHIC, MEDICAL, AND OPTICAL GOODS; WATCHES AND CLOCKS (EXCEPT AS NOTED BELOW) | 4-6 |
| | 386 | Photographic Equipment and Supplies | 7 |
| 39 | | MISCELLANEOUS MANUFACTURING INDUSTRIES | 3-7 |
| 49 | | ELECTRIC, GAS, AND SANITARY SERVICES | |
| | 491 | Electric Services | 3-5 |
| | 492 | Gas Production and Distribution | 3 |
| | 494 | Water Supply | 2 |
| | 4952 | Sewerage Systems | 2-5 |
| | 4953 | Refuse Systems (except Municipal Landfills) | 2-9 |
| | 496 | Steam Supply | 2-4 |

## TABLE V

### CONTAMINANT HAZARD POTENTIAL RANKINGS OF WASTES, CLASSIFIED BY TYPE[1] FOR STEP 4

| | Description | Hazard Potential Initial Rating | ID Number * |
|---|---|---|---|
| A. | SOLIDS | | |
| | Ferrous Metals | 1-4[2] | 1100 |
| | Non-Ferrous Metals | 1-7[2] | 1200 |
| | Resins, Plastics and Rubbers | 2 | 1300 |
| | Wood and Paper Materials (except as noted below) | 2 | 1400 |
| | - Bark | 4 | 1401 |
| | Textiles and Related Fibers | 2 | 1500 |
| | Inert Materials (except as noted below) | 2 | 1600 |
| | - Sulfide Mineral-Bearing Mine Tailings | 6 | 1601 |
| | - Slag and other Combustion Residues | 5 | 1602 |
| | - Rubble, Construction & Demolition Mixed Waste | 3 | 1603 |
| | Animal Processing Wastes (Except as noted below) | 2-4 | 1700 |
| | - Processed Skins, Hides and Leathers | 6 | 1701 |
| | - Dairy Wastes | 4 | 1702 |
| | - Live Animal Wastes-Raw Manures (Feedlots) | 5 | 1703 |
| | - Composts of Animal Waste | 2-4 | 1704 |
| | - Dead Animals | 5 | 1705 |
| | Edible Fruit and Vegetable Remains - Putrescables | 2-3 | 1800 |
| B. | LIQUIDS | | |
| | Organic Chemicals (Must be chemically Classified)[2] | | 2000 |
| | - Aliphatic (Fatty) Acids | 3-5 | 2001 |
| | - Aromatic (Benzene) Acids | 7-8 | 2002 |
| | - Resin Acids | | 2003 |
| | - Alcohols | 5-7 | 2004 |
| | - Aliphatic Hydrocarbons (Petroleum Derivatives | 4-6 | 2005 |
| | - Aromatic Hydrocarbons (Benzene Derivatives) | 6-8 | 2006 |
| | - Sulfonated Hydrocarbons | 7-8 | 2007 |
| | - Halogenated Hydrocarbons | 7-9 | 2008 |
| | - Alkaloids | 7-9 | 2009 |
| | - Aliphatic Amines and Their Salts | 1-4 | 2010 |
| | - Anilines | 6-8 | 2011 |
| | - Pyridines | 2-6 | 2012 |
| | - Phenols | 7-9 | 2013 |
| | - Aldehydes | 6-8 | 2014 |
| | - Ketones | 6-8 | 2015 |
| | - Organic Sulfur Compounds (Sulfides, Mercaptans) | 7-9 | 2016 |
| | - Organometallic Compounds | 7-9 | 2017 |
| | - Cyanides | 7-9 | 2018 |
| | - Thiocyanides | 2-6 | 2019 |
| | - Sterols | | 2020 |
| | - Sugars and Cellulose | 1-4 | 2021 |
| | - Esters | 6-8 | 2022 |

| Description | Hazard Potential Initial Rating | ID Number* |
|---|---|---|
| Inorganic Chemicals (Must be Chemically Classified)[2] | | 2100 |
| - Mineral and Metal Acids | 5-8 | 2101 |
| - Mineral and Metal Bases | 5-8 | 2102 |
| - Metal Salts, Including Heavy Metals | 6-9 | 2103 |
| - Oxides | 5-8 | 2104 |
| - Sulfides | 5-8 | 2105 |
| - Carbon or Graphite | 1-3 | 2106 |
| Other Chemical Process Wastes Not Previously Listed (Must be Chemically Classified)[2] | | 2200 |
| - Inks | 2-5 | 2201 |
| - Dyes | 3-8 | 2202 |
| - Paints | 5-8 | 2203 |
| - Adhesives | 5-8 | 2204 |
| - Pharmaceutical Wastes | 6-9 | 2205 |
| - Petrochemical Wastes | 7-9 | 2206 |
| - Metal Treatment Wastes | 7-9 | 2207 |
| - Solvents | 6-9 | 2208 |
| - Agricultural Chemicals (Pesticides, Herbicides, Fungicides, etc.) | 7-9 | 2209 |
| - Waxes and Tars | 4-7 | 2210 |
| - Fermentation and Culture Wastes | 2-5 | 2211 |
| - Oils, including Gasoline, Fuel Oil, etc. | 5-8 | 2212 |
| - Soaps and Detergents | 4-6 | 2213 |
| - Other Organic or Inorganic Chemicals, includes Radioactive Wastes | 2-9 | 2214 |
| Conventional Treatment Process Municipal Sludges | 4-8 | 2300 |
| - From Biological Sewage Treatment | 4-8 | 2301 |
| - From Water Treatment and Conditioning Plants (Must be Chemically Classified)[2] | 2-5 | 2302 |

* ID Number is for identification of waste type in the Reporting Form.

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[1] Classification based on material in Environmental Protection Agency Publication, 670-2-75-024, pages 79-85, Prepared by Arthur D. Little, Inc. and published in 1975.

[2] For individual material ranking refer to solubility-toxicity tables prepared by Versar, Inc. for the Environmental Protection Agency.

MOBILITY - The material must be able to enter the ground-water environment and travel with the ground water. Certain substances are essentially immobile (eg., asbestos fibers) while others are highly mobile with most substances falling between these extremes.

PERSISTENCE - Some substances such as halogenated hydrocarbons decay or degrade very slowly and receive a higher hazard potential ranking than other equally toxic materials that decay more rapidly.

VOLUME - Some substances, such as tailings or slimes from mining operations, are only moderately toxic but because they are produced in enormous quantities are given a somewhat higher hazard potential ranking.

CONCENTRATION - Substances entering the ground-water environment in concentrations which could potentially endanger human health are ranked. Concentration may decrease with dilution and attenuation but the amount of decrease at a given place depends, in part, on waste mobility, waste interaction with soils and aquifer material, etc.

## Determining the Waste Hazard Potential for Step 4 .

Wastes may be simple in composition, but most are complex and the hazard potential rankings given in Tables IV and V are maximum values based on the most hazardous substance present in the contaminant. Such rankings are, of necessity, generalizations because of the unknown interactions that occur between substances and the variables of the ground-water environment.

For those substances or sources that show a hazard potential ranking range (e.g., 5-8) additional information concerning the specific nature of the source or contaminant is required for assigning a specific ranking. Specific rankings in such cases must be personal judgements by the assessor. Additional information for determining a specific ranking may be available from the source of the contaminant, i.e., the industry may be able to supply specific information about the contaminant. In the event specific information is not available from the source, additional information may be obtained from an examination of descriptions of average contaminant characteristics listed in several publications cited below. For cases when there is considerable pretreatment of the waste, the ranking may be lowered to the bottom of its range. If no additional information is available, the first round approximation ranking must assume the worst case and a low confidence rating be given the ranking.

If sufficient information exists about the material (i.e., exact composition, concentration, volume, treatment prior to coming in contact with the ground, etc.) the rating may be lowered. In considering whether to lower the rating, some compounds degrade aerobically or anaerobically and the products of degradation are more hazardous than the parent chemical. Initial rankings may be modified downward provided:

1. The hazardous material in question has been effectively treated to lower its hazard potential as a ground-water pollutant. Several references describe best available methods for treating contaminants to reduce their toxicity, for example see:

- Sax, 1965, Dangerous Properties of Industrial Materials.
- Identification of Potential contaminants of underground water sources from land spills, by Versar, Inc. (Task II of EPA contract No. 68-01-4620.
- EPA, 1973, Report to Congress on Hazardous Waste Disposal
- Powers, 1976, How to Dispose of Toxic Substances and Industrial Wastes.

2. It can be shown that the hazardous material in question has low mobility in the specific site it is contaminating. Most solid and inert substances have low mobility. Substances with high solubilities tend to be most mobile. Mobility depends on a complex interplay of many factors and only a few substances have been studied sufficiently to predict with any degree of confidence their specific mobilities at a specific site.

3. The volume and/or concentration of the hazardous material is so small that there is a good probability that it will be diluted to safe (drinking water standard) levels at the point of concern.

### Example for Determining the Score for Step 4 .

The waste in the Poultry Processing Plant lagoon is a meat product waste, SIC number 201 and would receive a "3" rating.

## STEP 5

## DETERMINATION OF THE SITE'S OVERALL GROUND-WATER CONTAMINATION POTENTIAL

After the site has been rated on Steps 1, 2, 3 and 4, the overall ground-water contamination potential of the site can be determined by totalling these scores. This overall score allows a comparison of one site with other rated sites by indicating the general, overall contamination potential. Sites may be rated identically, yet be very different in one or several of the parameters included in the overall score; thus the overall score of Step 5 should be used with caution in assessing a particular site's potential to allow ground-water contamination. In addition, this overall score cannot be used to assess the actual amount of ground-water contamination at the site. The score is only for relative comparison with other sites. An actual determination of ground-water contamination requires an intensive on-site investigation.

EPA has not formulated an interpretation of the overall ground water contamination score other than as a relative means to prioritize sites.

### Step 5. Determination of the Site's Ground-Water Contamination Potential Rating.

The site's ground-water contamination potential rating is the addition of the rating scores for the first four steps:

Contamination Potential = Step 1 + Step 2 + Step 3 + Step 4.

The highest ground-water contamination potential rating a site can receive is "29" while the lowest is "1."

Example for determining the score for Step 5.

The overall ground-water contamination potential score for the Poultry Processing Plant lagoon is determined in Step 5 by adding the scores from Steps 1, 2, 3, and 4:

Step 5 Rating = Step 1 + Step 2 + Step 3 + Step 4

= 9 + 4 + 5 + 3 = 21

# STEP 6

# DETERMINATION OF THE POTENTIAL ENDANGERMENT TO CURRENT WATER SUPPLIES

The distance from the impoundment to a ground or surface water source of drinking water and the determination of anticipated flow direction of the waste plume are used to ascertain the potential endangerment to current water supplies presented by the surface impoundment. For many assessments this step can be accomplished by measuring the horizontal distance on a 7.5 topographic map, or similar scale. In order to use this step, the anticipated direction of ground water flow within 1600 meters (1 mile) of the impoundment must be determined. Groundwater movement depends upon natural ground-water flow direction, variations due to pumping wells, mounding of the ground water beneath the site and other factors influencing flow direction, such as faults, fractures and other geologic features.

In the case of artesian wells, the anticipated flow direction of the waste plume generally would not be in the direction of the artesian well intake. Artesian wells are located in confined aquifers separated hydraulically from the surface sources of contamination by relatively impermeable confining layers, and wells tapping the confined zone generally will not be drawing ground water from upper zones.

Artesian wells should not be considered in this step unless there is an indication that the anticipated flow direction of the contaminated ground water would be in the direction of that well. To score Step 5, prioritized cases (cases A-D) have been established for rating the site according to the potential magnitude of endangerment to current sources. These priorities are detailed in Step 6 (Table VI). To score a site when a water table is nearly flat and the flow direction is indeterminable, a circle with a 1600 meter radius should be drawn around the site for designating the area of concern. In this situation the evaluator would use the same criteria, in sequential order, begining with Case A, Case B, and then Case D, eliminating Case C.

After the distance has been determined, use the Step 6 rating matrix to determine the rating under the column of the appropriate case.

## TABLE VI

Step 6. Rating the Potential Endangerment to a Water Supply

| | | |
|---|---|---|
| Case A | - | Highest Priority: Rate the closest water well within 1600 meters of the site that is in the anticipated direction of waste plume movement. |
| Case B | - | Second Priority: If there is no well satisfying Case A, rate the closest surface water within 1600 meters of the site that is in the anticipated direction of the waste plume movement. |
| Case C | - | Third Priority: If no surface water or water well satisfying Case A or B exists, rate the closest water supply well or surface water supply within 1600 meters of the site that is not in the anticipated direction of waste plume movement. |
| Case D | - | Lowest Priority: If there are no surface waters or water wells within 1600 meters of the site in any direction, rate the site as "0D." |

Select the appropriate rating for the given distance and case:

| Distance (Meters) | Case A | Case B | Case C | Case D |
|---|---|---|---|---|
| ≤ 200 | 9A | 8B | 7C | - |
| >200, ≤ 400 | 7A | 6B | 5C | - |
| >400, ≤800 | 5A | 4B | 3C | - |
| >800, ≤1600 | 3A | 2B | 1C | - |
| >1600 | | | | 0D |

## Example for determining the score for Step 6.

The potential health hazard to existing water supply sources which the Poultry Processing Plant presents is found by determining what types of water supplies are present and their distances from the lagoon. The drilled well described in Figure 11 is for industrial water supply. Surface water (a river) is within about 30 meters of the lagoon as shown in Figure 9. Step 6 requires an estimation of the anticipated flow direction. In this example, the anticipated flow of the waste plume is to the river. The rating of Step 6 would be based on Case B, and would be scored "8B".

## STEP 7

## DETERMINING THE INVESTIGATOR'S DEGREE OF CONFIDENCE

The evaluation of a surface impoundment's ground-water contamination potential involves three steps and about twice as many separate variables. In many situations the investigator will not have comprehensive information concerning the variables and will have to evaluate the site on the basis of estimation or approximation. For this reason a rating of the investigator's confidence in scoring each step will be made. The following outline is intended to assist the investigator in rating the confidence of the data for each step, with "A" the highest confidence, "C" the lowest.

Step 1 confidence rating for determining the earth material of the unsaturated zone.

| Rating | Basis for Determination of Rating |
|---|---|
| A | Driller's logs containing reliable geologic descriptions and water level data;<br>U. S. Department of Agriculture soil survey used in conjunction with large scale, modern geologic maps.<br>Published ground-water reports on the site. |
| B | Soil surveys or geologic maps used alone. |

| | |
|---|---|
| | General ground-water reports.<br>Drillers' logs with generalized descriptions.<br>Drillers logs or exposures such as deep road cuts near the site of contamination allowing interpolation within the same general geologic unit. |
| C | On site examination with no subsurface data and no exposures of subsurface conditions nearby.<br>Estimation of water levels or geology based on topography and climate.<br>Extrapolations of well logs, road cuts, etc. where local geology is not well known.<br>Estimation based on generalized geologic maps.<br>Estimations based on topographic analysis. |

### Step 2 confidence rating for determining the ground-water availability ranking.

This step involves the earth material categorization and thickness of the aquifer's saturated zone. The confidence rating for Step 2, Part A follows the same basis as Step 1, Part B above.

### Step 3 confidence rating for determining background ground-water quality.

| Rating | Basis for Determination of Rating |
|---|---|
| A | Water quality analyses indicative of background ground-water quality from wells at the site or nearby wells or springs or known drinking water supply wells in vicinity. |

| | |
|---|---|
| B | Local, county, regional and other general hydrogeology reports published by State or Federal agencies on background water quality.<br>Interpolation of background ground-water quality from base flow water quality analyses of nearby surface streams. |
| C | Estimates of background ground-water quality from mineral composition of aquifer earth material. |

Step 4 confidence rating for waste character.

| Rating | Basis for Determination of Rating |
|---|---|
| A | Waste character rating based on specific waste type. |
| B | Waste character rating based on SIC category. |

Step 6 confidence rating for determination of the anticipated direction of waste plume movement.

| Rating | Basis for Determination of Rating |
|---|---|
| A | Accurate measurements of elevations of static water levels in wells, springs, swamps, and permanent streams in the area immediately surrounding the site in question.<br>Ground-water table maps from published State and Federal reports. |

| | |
|---|---|
| B | Estimate of flow direction from topographic maps in non cavernous area having permanent streams and humid climate. |
| | Estimate of flow direction from topographic maps in arid regions of low relief containing some permanent streams. |
| C | Estimate of flow direction from topographic maps in cavernous, predominantly limestone areas (karst terrain). |
| | Estimate of flow direction from topographic maps in arid regions of highly irregular topography having no permanent surface streams. |

### Example for determining the confidence rating for each step.

Based upon the guidance just presented, the confidence ratings for the Poultry Processing Plant are:

| | Confidence Rating |
|---|---|
| Step 1 | A--Based upon measurement in on site well. |
| Step 2 | A--Based upon well logs of on site well. |
| Step 3 | A--Based upon water well analyses. |

| | |
|---|---|
| Step 4 | B--Based upon SIC category. |
| Step 6 | B--Estimate of flow direction from topographic map in humid region. |

## STEP 8

## MISCELLANEOUS IDENTIFIERS

This step allows the evaluator to identify any additional significant variable not noted in the rating system. Such parameters are:

Identifier

R - The site is located in a ground-water recharge area,

D - The site is located in a ground-water discharge area,

F - The site is located in a flood plain and is susceptable to flood hazard,

E - The site is located in an earthquake prone area,

W - The site is located in the area of influence of a pumping water supply well,

K - The site is located in karst topography or fractured, cavernous limestone region.

C - The ground water under the site has been contaminated by man-made causes (i. e., road salt, feed lot, industrial waste).

M - Known ground-water mound exists beneath the site.

I - Interceptor wells or other method employed to inhibit contaminated ground-water migration (endangerment to water supply wells may be reduced).

## STEP 9

## RECORD THE FINAL SCORE

In order to present the rating scores from the previous nine steps of the evalution system in a logical manner, Step 9 provides a systematic format in which the evaluation of the site can be recorded. The nine steps are not recorded in numerical order as the focus of the evaluation is on the ground-water pollution potential score of Step 5. Thus, Step 5 is listed first, followed by Steps 1, 2, 3, 4, 6 and 8. The example of the Poultry Processing Plant waste treatment lagoon has been listed on page 63 on the following sample reporting form. The confidence scores of Step 7 have been distributed among the appropriate steps.

## TABLE VII

RATING OF THE GROUND WATER POLLUTION POTENTIAL:

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | C | A | 4 | C | A | 5 | A | 3 | B | 2 | 1 | 8 | B | B | R | F | |
| Unsat. Zone | | Confidence | G. W. Avail. | | Confidence | G. W. Qual. | Confidence | Waste | Confidence | G. W. Poll. Potential | | Health Hazard | | Confidence | Miscellaneous Identifiers | | |
| STEP 1 | | | STEP 2 | | | STEP 3 | | STEP 4 | | STEP 5 | | STEP 6 | | | | | |

## APPENDIX A

## TYPICAL SOURCES AND TYPES OF DATA USEFUL IN APPLYING THE ASSESSMENT SYSTEM

| Type of Data | Typical Sources | Useful in determining Steps | | | |
|---|---|---|---|---|---|
| | | 1 | 2&3 | 4 | 6 |
| Property survey | County Records, property owner | * | | X | |
| Well drillers logs | Well Driller, property owner, state records | * | * | | X |
| Water level measurements | Well owners' observations, well drillers' logs, topographic maps, ground water maps (reports) | * | X | | * |
| Topographic Maps | U.S. Geological Survey and designated state sales offices | X | | | * |
| Air Photos | U.S. Dept of Agriculture, U.S. Forest Service, etc. | | | | * |
| County Road Maps | State agencies | | | | * |
| Ground Water Reports | U.S. Geological Survey, State agencies | * | * | | X |
| Soil Surveys of Counties | U.S. Department of Agriculture | * | X | | X |
| Geologic Maps | U.S. Geological and State Surveys | X | X | | X |
| Waste Character | Owner/operator, State or Federal permits, SIC Code | | | X | |

* - Source of data may be especially useful

X - Source of data may be of slight use or may be used indirectly

## APPENDIX B

## MEASURING UNIT CONVERSION TABLE

inch (in) x 2.54 = centimeter (cm)

centimeter x 0.3937 = inch

feet (ft) x 0.3048 = meter (m)

meter x 3.2808 = feet

mile (mi) x 1.609 = kilometer (km)

kilometer x 0.621 = mile

U.S. gallon (gal) x 0.0038 = cubic meter ($m^3$)

cubic meter x 264.17 = U.S. gallon

cubic feet ($ft^3$) x 0.0283 = cubic meter

cubic meter x 35.314 = cubic feet

acre-foot (ac-ft) x 123.53 = cubic meter

cubic meter x 0.0008 = acre-feet

hectare x 10,000.0 = square meter ($m^2$)

square meter x 0.0001 = hectare

hectare x 2.471 = acre

acre x 0.4047 = hectare

**Hydraulic Conductivity**

gpd/$ft^2$ x $4.72 \times 10^{-5}$ = cm/sec

cm/sec x $21.2 \times 10^{3}$ = gpd/$ft^2$

Darcy x 18.2 = gpd/$ft^2$

Darcy x $8.58 \times 10^{-4}$ = cm/sec

## APPENDIX C

## GLOSSARY

**Aquifer** - a formation, group of formations or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

**Artesian ground water** - synonymous with confined ground water which is a body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying ground water. Confined ground water is under pressure great enough to cause water in a well tapping that aquifer to rise above the top of the confined aquifer.

**Discharge area** - geographic region in which ground water discharges into surface water such as at springs and seeps and subsurface seepage into streams, lakes and oceans (referred to as base flow in streams).

**Karst topography** - geologic region typified by the effects of solution of rocks by water. Rock types most likely effected are limestone dolostone, gypsum and salt beds. Features produced are caverns, collapse features on the surface (sink holes), underground rivers and zones of lost circulation for well drillers.

**Perched water table** - unconfined ground water separated from an underlying body of ground water by an unsaturated zone. Its water table is a "perched water table" and is sustained by a "perching bed" whose permeability is so low that water percolating downward through it is not able to bring water in the underlying unsaturated zone above atmospheric pressure.

**Plume of contaminated ground water** - as contaminants seep or leach into the subsurface and enter the ground water, the flow of the ground water past the site of contamination causes the contaminated ground water to move down gradient. This action results in the creation of a "plume" shaped body of ground water containing varying concentrations of the contaminant, extending down gradient from place of entry. The shape of the plume of contaminated ground water is affected by attenuation of the specific contaminants and, to a lesser extent, by dispersion.

**Primary permeability** - permeability due to openings or voids existing when the rock was formed, i. e. , intergranular interstices.

Recharge area - geographic region in which surface waters infiltrate into the ground, percolate to the water table and replenish the ground water. Recharge areas may be well defined regions such as limestone outcrops or poorly defined broad regions.

Saturated Zone - the zone in the subsurface in which all the interstices are filled with water.

Secondary permeability - permeability due to openings in rocks formed after the formation of the rock, i. e., joints, fractures, faults, solution channels and caverns.

Unsaturated zone - formerly the "zone of aeration" or "vadose zone". It is the zone between the land surface and the water table, including the "capillary fringe".

Water table - that surface in an unconfined ground-water body at which the pressure is atmospheric. Below the water table is the saturated zone and above is the unsaturated zone.

# APPENDIX D

## SELECTED REFERENCES

Alexander, Martin, "The Breakdown of Pesticides in Soils, in Brody, N. C.," *Agriculture and the Quality of Our Environment*, Plimpton Press, Norwood, Massachusetts, pp 331-342, 1967.

Belter, W. G., "Ground Disposal: Its Role in the U. S. Radioactive Waste Management Operations,: in *Comptes Rendus, Collogue International sur la Retention et la Migration de Jons Radioactifs dans les Sols*, Centre d'Etudes Nucleaires, Saclay, France, pp 3-10, 1963.

Bredehoeft, J. D., and G. F. Pinder, "Mass Transport in Flowing Groundwater," *Water Resources Research*, Vol 9, No. 1, pp 194-210, 1973.

Born, S. M., and D. A. Stephenson, "Hydrogeologic Considerations in Liquid Waste Disposal," *Journal of Soil and Water Conservation*, Vol 24, No. 2, pp 52-55, 1969.

Brown, R. E., *Hydrologic Factors Pertinent to Ground-Water Contamination*, Public Health Service Technical Report W61-5, pp 7-20, 1961.

Brown, R. H., and J. R. Raymond, "The Measurements of Hanford's Geohydrologic Features Affecting Waste Disposal," in *Proceedings of the Second Atomic Energy Commission Working Meeting - Ground Disposal of Radioactive Waste, Chalk River, Canada*, U. S. Department of Commerce TID 7628, pp 77-98, 1962.

Carlston, C. W., "Tritium - Hydrologic Research: Some Results of the U. S. Geological Survey Research Program," *Science 143* (3608), pp 804-806, 1964.

Cartwright, K., and F. B. Sherman, "Evaluating Sanitary Landfill Sites in Illinois," *Illinois State Geological Survey Environmental Geology* Note No. 27, 15 pp, August 1969.

Cherry, J. A., G. E. Grisak, and R. E. Jackson, "Hydrogeological Factors in Shallow Subsurface Radioactive-Waste Management in Canada," *Proceedings International Conference on Land For Waste Management*, Ottawa, Canada, October 1-3, 1973.

Clark, D.A. and J.E. Moyer, 1974, An Evaluation of Tailings Ponds Sealants, EPA-660/2-74-065.

Cole, J.A. (ed.), Groundwater Pollution in Europe, Water Information Center, Port Washington, New York, 347 pp, 1975.

DaCosta, J.A., and R.R. Bennett, "The Pattern of flow in the Vicinity of a Recharging and A Discharging Pair of Wells in an Aquifer Having Areal Parallel Flow," International Union Geodesy and Geophysic, International Association Committee Subterranean Waters, 1961.

Davis, S.N. and R.J.M. DeWiest, 1966, Hydrogeology, John Wiley and Sons, Inc., New York.

DeBuchannanne, G.D., and P. E. LaMoreaux, Geologic Control Related to Ground Water Contamination, Public Health Service Technical Report W61-5, pp 3-7, 1961.

Deutsch, M., Groundwater Contamination and Legal Controls in Michigan, Public Health service Technical Report W61-5, pp 98-110., 1961.

Ellis, M.J. and D.T. Pederson, 1977, Groundwater Levels in Nebraska, 1976, Conservation and Survey Division, University of Nebraska-Lincoln.

Engineering-Science, Inc., "Effects of Refuse Dumps on Groundwater Quality," Resources Agency California State Water Pollution Control Board, Pub. 211, 1961.

Geswein, A.J. and 1975, Liners for Land Disposal Sites--An Assessment, EPA/530/SW-137.

Giddings, M.T., "The Lycoming County, Pennsylvania, Sanitary Landfill: State-of-the-Art in Ground-Water Protection," Ground Water, Vol 2, Special Issue, pp 5-14, 1977.

Haxo, H.E., Jr., and R.M. White, 1976, Evaluation of Liner Materials Exposed to Leachate, Second Interim Report, EPA-600/2-76-255.

Haxo, R.S. and R.M. White, 1977, Liner Materials Exposed to Hazardous and Toxic Sludges, First interim Report, EPA-600/2-77-081.

Hughes, J.L., Evaluation of Ground-Water Degradation Resulting From Waste Disposal to Alluvium Near Barstow, California, U.S. Geological Survey Prof. Paper 878, 33 pp, 1975.

Hughes, G.M., and K. Cartwright, "Scientific and Administrative Criteria for Shallow Waste Disposal," Civil Engineering-ASCE, Vol 42, No. 3, pp 70-73, 1972.

Hughes, G.M., R.A. Landon, and R.N. Farvolden, Hydrogeology of Solid Waste Disposal Sites in Northeastern Illinois, U.S. Environmental Protection Agency, Report SW-122, 154 pp, 1971.

LeGrand, H.E., "System for Evaluating the Contamination Potential of Some Waste Sites," American Water Works Association Journal, Vol 56, No. 8, pp 959-974, 1964a.

LeGrand, H.E., "Management Aspects of Ground-Water Contamination," Journal Water Pollution Control Federation, Vol 36, No. 9, pp 1133-1145, 1964b.

LeGrand, H.E., "Patterns of Contaminated Zones of Water in the Ground," Water Resources Research, Vol 1, No. 1, pp 83-95, 1965.

LeGrand, H.E., "Monitoring the Changes in Quality of Ground Water," Ground Water, Vol 6, No. 3, pp 14-18, 1968.

Lieber, Maxim, N.M. Perlmutter, and H.L. Frauenthal, "Cadmium and Chromium in Nassau County Groundwater," Journal American Water Works Association, Vol 56, No. 6, p 742, 1964.

Meyer, C.F. (ed.), Polluted Groundwater: Some Causes, Effects, Controls and Monitoring, U.S. Environmental Protection Agency, Report No. EPA-600/4-73-001b, Washington, D.C., 325 pp, June 1974.

Miller, D.W., F.A. Deluca, and T.L. Tessier, Ground Water Contamination in the Northeast States, U.S. Environmental Protection Agency, Report No. EPA-660/2-74-056, Washington, D.C., 325 p, June 1974.

Miller, D.W. (editor), Waste Disposal Practices and Their Effects on Ground Water, U.S. Environmental Protection Agency, Report No. EPA-570/9-77-001, Final Report to Congress, 1977.

Morrison, W.R., R.A. Dodge, J. Merriman, C.M. Ellsperman, Chungming Wong, W.F. Savage, W.W. Rinne and C.L. Granses, 1970, Pond Linings for Desalting Plant Effluents, U.S. Dept. of the Interior, Office of Saline Water, Research and Development Progress Report No. 602.

Palmquist, R., and L.V.A. Sendlein, "The Configuration of Contamination Enclaves from Refuse Disposal Sites on Floodplains, Ground Water, Vol 13, No. 2, pp 167-181, 1975.

Panel on Land Burial, Committee on Radioactive Waste Management, The Shallow Land Burial of Low-Level Radioactively Contaminated Solid Waste, National Research Council, National Academy of Sciences, Washington, D. C., 150 pp 1976.

Papadopolos, S. S., and I. J. Winograd, Storage of Low-Level Radioactive Wastes in the Ground Hydrogeologic and Hydrochemical Factors with an Appendix on the Maxey Flats, Kentucky, Radioactive Waste Storage Site: Current Knowledge and Data Needs for a Quantitative Hydrogeologic Evaluation, U.S. Environmental Protection Agency, Report No. EPA-520/3-74-009, Reston, Virginia, 40 pp, 1974.

Parsons, P. J., "Underground Movement of Radioactive Wastes at Chalk River," in Proceedings of the Second Atomic Energy Commission Working Meeting - Ground Disposal of Radioactive Wastes, Chalk River, Canada, U.S. Department of Commerce, TID 7628, pp 17-64, 1962.

Perlmutter, N M., M. Lieber, and H. L. Frauenthal, "Waterborne Cadmium and Hexavalent Chromium Wastes in South Farmingdale, Nassau County, Long Island, New York," U.S. Geological Survey Prof. Paper 475-C, pp 179-184, 1963.

Peters, J.A., 1968, Ground Water Course, State of California, The Resources Agency, Dept. of Water Resources, Sacramento, Calif., pp. 5-7.

Pettyjohn, W.A., "Water Pollution in Oil Field Brines and Related Industrial Wastes in Ohio," in Water Quality in a Stressed Environment, Burgess Publishing Company, Minneapolis, Minnesota, pp 166-180, 1972.

Phillips, C.R., Development of a Soil-Waste Interaction Matrix, Canada, Environmental Protection Service, Solid Waste Management Report EPS-EX-76-10, 89 pp, 1976.

Pinder, F. F., "A Galekin -Finite Element Simulation of Groundwater Contamination on Long Island, New York," Water Resources Research, Vol. 9, No. 6, pp 1657-1669, 1973.

Pinder, G. G., W.P. Saukin and M. Th. Van Genuchten, 1976, Use of Simulation for Characterizing Transport in Soils Adjacent to Land Disposal Sites, Research Report 76-WR-6, Water Resources Program, Department of Civil Engineering, Princeton University.

Robson, S.G., and J.D. Bredehoeft, "Use of a Water Quality Model for the Analysis of Ground Water Contamination at Barstow, California," *Geological Society of America Abstracts with Programs*, Annual Meetings, Vol 4, No. 7, pp 640-641, 1972.

Romero, J.C., "The Movement of Bacteria and Viruses through Porous Media," *Ground Water*, Vol 8, No. 2, pp 37-48, 1970.

Sendlein, L.V.A., and R.C. Palmquist, "Strategic Placement of Waste Disposal Sites in Karst Regions,: in *Karst Hydrology, Memoirs of the 12th Congress of the International Association of Hydrogeologists*, published by University of Alabama at Huntsville Press, pp 328-335, 1977.

Simpson, E.S., *Transverse Dispersion in Liquid Flow through Porous Media*, U.S. Geological Survey Prof. Paper 411-C, 30 pp, 1962.

Theis, C.V., "Notes on Dispersion in Fluid Flow by Geological Factors," in *Proceedings of the Second Atomic Energy Commission Working Meeting, Ground Disposal of Radioactive Wastes, Chalk River, Canada*, U.S. Department of Commerce TID 7628, pp 166-178, 1962.

Thomas, Henry, "Some Fundamental Problems in the Fixations of Radioisotopes in Solids," *Proceedings U.N. International Conference: Peaceful Uses Atomic Energy, 18*, pp 37-42, 1958.

Todd, D.K., 1959, *Ground Water Hydrology*, John Wiley and Sons, Inc., New York, p. 53.

______________, 1970, *The Water Encyclopedia*, The Water Information Center Inc., 559 pp.

Todd, D.K., and E.E. McNulty, *Polluted Groundwater: A Review of the Significant Literature*, U.S. Environmental Protection Agency, Report No. EPA-680/4-74-001, Washington, D.C., 215 pp, March 1974.

Todd, D.K., R.M. Tinlin, K.D. Schmidt, and L.G. Everett, *Monitoring Groundwater Quality: Monitoring Methodology*, U.S. Environmental Protection Agency, Report No. EPA-600/4-76-026, Las Vegas, Nevada, 154 pp, June 1976.

Vogt, J.E., "Infectious Hepatitis Outbreak in Posen, Michigan," in *Ground Water Contamination, Proceedings of 1961 Symposium*, pp 87-91, 1961.

Walton, W.C., 1970, Ground Water Resource Evaluation, McGraw-Hill Book Co., New York, p. 36.

Waltz, J.P., "Methods of Geologic Evaluation of Pollution Potential at Mountain Homesites," Ground Water, Vol 10, No. 1, pp 42-47, 1972.

Walz, D.H., and K.T. Chestnut, "Land Disposal of Hazardous Wastes: An Example from Hopewell, Virginia," Ground Water, Vol 15, No. 1, pp 75-79, 1977.

Wenzel, L.K., Methods for Determining Permeability of Water-Bearing Materials, U.S. Geological Survey Water Supply Paper 887, 1942.

# APPENDIX B

## APPENDIX B-I

## LOCATED ACTIVE SITES & IMPOUNDMENTS

|  | Agricultural |  | Municipal |  | Industrial |  | Mining |  | Oil & Gas |  | Other |  | Total |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps |
| AK | 11 | 12 | 107 | 142 | 10 | 22 | 1 | 3 |  |  |  |  | 129 | 179 |
| AL | 404 | 409 | 378 | 562 | 249 | 628 | 33 | 96 | 1 | 1 |  |  | 1065 | 1696 |
| AR | 204 | 236 | 346 | 490 | 163 | 322 | 16 | 29 | 132 | 5729 |  |  | 861 | 6806 |
| AS |  |  | 2 | 2 | 2 | 3 |  |  |  |  |  |  | 4 | 5 |
| AZ | 52 | 86 | 374 | 980 | 135 | 336 | 79 | 211 | 1 | 2 |  |  | 641 | 1615 |
| CA | 190 | 394 | 839 | 3390 | 523 | 1596 | 81 | 183 | 117 | 2014 |  |  | 1750 | 7577 |
| CO | 221 | 392 | 443 | 823 | 263 | 939 | 78 | 216 | 262 | 1261 |  |  | 1267 | 3631 |
| CT | 18 | 19 | 120 | 359 | 162 | 372 | 5 | 8 |  |  |  |  | 305 | 758 |
| DE | 5 | 10 | 14 | 35 | 33 | 86 |  |  |  |  |  |  | 52 | 131 |
| FL | 312 | 509 | 2527 | 3505 | 747 | 1306 | 58 | 290 |  |  |  |  | 3644 | 5610 |
| GA | 733 | 748 | 430 | 513 | 158 | 293 | 42 | 86 |  |  |  |  | 1363 | 1640 |
| GM | 6 | 31 | 34 | 48 | 10 | 80 | 19 | 37 |  |  | 33 | 38 | 102 | 234 |
| HI | 43 | 50 | 30 | 44 | 21 | 202 |  |  |  |  |  |  | 94 | 296 |
| IA | 576 | 721 | 759 | 1268 | 100 | 194 | 6 | 13 |  |  | 343 | 343 | 1784 | 2539 |
| ID | 38 | 67 | 134 | 311 | 50 | 110 | 31 | 50 |  |  |  |  | 253 | 538 |
| IL | 171 | 246 | 978 | 2142 | 380 | 974 | 132 | 264 | 2810 | 3051 |  |  | 4471 | 6677 |
| IN | 578 | 766 | 480 | 666 | 213 | 492 | 146 | 264 | 480 | 490 |  |  | 1897 | 2678 |
| KS | 1020 | 1816 | 422 | 833 | 107 | 245 | 3 | 5 | 418 | 429 |  |  | 1970 | 3328 |

## LOCATED ACTIVE SITES & IMPOUNDMENTS

| State | Agricultural | | Municipal | | Industrial | | Mining | | Oil & Gas | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps |
| KY | 61 | 131 | 199 | 262 | 147 | 259 | 124 | 152 | 109 | 118 | | | 640 | 922 |
| LA | | | 72 | 113 | 213 | 865 | 3 | 8 | 696 | 1818 | | | 984 | 2804 |
| MA | 8 | 20 | 210 | 1811 | 122 | 377 | 1 | 3 | | | | | 341 | 2211 |
| MD | 79 | 97 | 79 | 122 | 124 | 248 | 161 | 369 | | | | | 443 | 836 |
| ME | 28 | 33 | 56 | 111 | 48 | 175 | | | | | | | 132 | 319 |
| MI | 557 | 659 | 689 | 1063 | 891 | 1648 | 50 | 135 | | | | | 2187 | 3505 |
| MN | 1404 | 1530 | 381 | 866 | 112 | 277 | 55 | 60 | | | | | 1952 | 2733 |
| MO | 2006 | 2123 | 1318 | 2035 | 282 | 436 | 51 | 89 | | | | | 3657 | 4683 |
| MS | 421 | 476 | 476 | 533 | 399 | 640 | 5 | 10 | 5 | 8 | | | 1306 | 1667 |
| MT | 85 | 129 | 227 | 466 | 61 | 233 | 31 | 107 | 264 | 331 | | | 668 | 1266 |
| NC | 100 | 132 | 256 | 352 | 339 | 542 | 14 | 25 | | | | | 709 | 1051 |
| ND | 248 | 285 | 363 | 748 | 8 | 26 | 25 | 85 | 23 | 24 | | | 667 | 1168 |
| NE | 619 | 1139 | 360 | 702 | 81 | 227 | 1 | 1 | 570 | 1183 | 1 | 2 | 1632 | 3254 |
| NH | 15 | 22 | 107 | 202 | 30 | 50 | | | | | | | 152 | 274 |
| NJ | 3 | 8 | 74 | 185 | 219 | 670 | 15 | 33 | | | | | 311 | 896 |
| NM | 88 | 142 | 337 | 863 | 293 | 732 | 86 | 836 | 12097 | 15173 | | | 12901 | 17746 |
| NV | 3 | 11 | 87 | 259 | 24 | 82 | 102 | 189 | | | | | 216 | 541 |
| NY | 71 | 56 | 395 | 684 | 299 | 645 | 28 | 119 | 277 | 333 | | | 1070 | 1837 |
| OH | 154 | 184 | 458 | 727 | 854 | 1528 | 541 | 12753 | 1280 | 1345 | | | 3287 | 16537 |
| OK | 330 | 429 | 749 | 1316 | 224 | 422 | 85 | 138 | 1547 | 2233 | | | 2935 | 4538 |
| OR | 58 | 74 | 211 | 396 | 90 | 214 | 11 | 30 | | | | | 370 | 714 |

## LOCATED ACTIVE SITES & IMPOUNDMENTS

| State | Agricultural | | Municipal | | Industrial | | Mining | | Oil & Gas | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps |
| PA | 249 | 339 | 404 | 761 | 668 | 1680 | 4331 | 5611 | 571 | 20471 | 1123 | 5362 | 7346 | 34224 |
| PR | 300 | 302 | 4 | 4 | 23 | 78 | | | | | | | 327 | 384 |
| RI | 9 | 17 | 8 | 24 | 27 | 92 | | | | | | | 44 | 133 |
| SC | 1068 | 1107 | 595 | 753 | 203 | 397 | 2 | 2 | | | | | 1868 | 2259 |
| SD | 279 | 343 | 276 | 487 | 20 | 51 | 4 | 14 | 27 | 31 | | | 606 | 926 |
| TN | 271 | 368 | 143 | 177 | 211 | 484 | 121 | 296 | | | | | 746 | 1325 |
| TT | | | 3 | 5 | | | | | | | | | 3 | 5 |
| TX | 510 | 1181 | 761 | 1658 | 612 | 2272 | 47 | 144 | 1742 | 5485 | | | 3672 | 10740 |
| UT | 6 | 8 | 42 | 182 | 30 | 78 | 3 | 10 | 130 | 2067 | | | 211 | 2345 |
| VA | 393 | 557 | 399 | 546 | 254 | 507 | 166 | 365 | | | | | 1212 | 1975 |
| VI | | | 7 | 7 | 2 | 10 | | | | | | | 9 | 17 |
| VT | 128 | 130 | 64 | 96 | 21 | 45 | 1 | 3 | | | | | 214 | 274 |
| WA | 133 | 174 | 168 | 360 | 91 | 468 | 11 | 47 | | | | | 403 | 1049 |
| WI | 392 | 427 | 301 | 644 | 323 | 635 | 6 | 14 | | | | | 1022 | 1720 |
| WV | 13 | 16 | 322 | 408 | 104 | 348 | 249 | 1089 | | | | | 688 | 1861 |
| WY | 6 | 8 | 88 | 138 | 44 | 99 | 40 | 139 | 968 | 1354 | | | 1146 | 1738 |

## APPENDIX B-II

## ASSESSED ACTIVE SITES & IMPOUNDMENTS

| State | Agricultural | | Municipal | | Industrial | | Mining | | Oil & Gas | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps |
| AK | 6 | 6 | 38 | 38 | 7 | 7 | 1 | 2 | | | | | 52 | 53 |
| AL | 201 | 201 | 169 | 169 | 83 | 83 | 14 | 14 | | | | | 467 | 467 |
| AR | 46 | 46 | 146 | 146 | 153 | 153 | 14 | 14 | 131 | 131 | | | 490 | 490 |
| AS | | | | | | | | | | | | | 0 | 0 |
| AZ | 5 | 5 | 43 | 43 | 92 | 92 | 18 | 18 | | | | | 158 | 158 |
| CA | 172 | 194 | 736 | 1087 | 475 | 613 | 79 | 97 | 107 | 117 | | | 1629 | 2108 |
| CO | 35 | 35 | 68 | 68 | 36 | 37 | 10 | 10 | 40 | 41 | | | 189 | 191 |
| CT | 14 | 14 | 107 | 107 | 158 | 158 | 5 | 5 | | | | | 284 | 284 |
| DE | 5 | 10 | 14 | 36 | 32 | 85 | | | | | | | 51 | 131 |
| FL | 311 | 508 | 2523 | 3487 | 740 | 1299 | 57 | 289 | | | | | 3631 | 5583 |
| GA | 251 | 251 | 141 | 141 | 117 | 117 | 28 | 28 | | | | | 537 | 537 |
| GM | 6 | 6 | 32 | 32 | 10 | 10 | 18 | 18 | | | 33 | 33 | 99 | 99 |
| HI | 42 | 46 | 30 | 37 | 21 | 41 | | | | | | | 93 | 124 |
| IA | 57 | 57 | 74 | 74 | 80 | 80 | | | | | | | 211 | 211 |
| ID | 38 | 38 | 128 | 129 | 46 | 46 | 30 | 30 | | | | | 242 | 243 |
| IL | 170 | 170 | 204 | 204 | 379 | 379 | 130 | 130 | 183 | 183 | | | 1066 | 1066 |
| IN | 569 | 569 | 477 | 477 | 206 | 206 | 146 | 146 | 473 | 473 | | | 1871 | 1871 |
| KS | 100 | 100 | 42 | 42 | 49 | 49 | | | 20 | 20 | | | 211 | 211 |

## ASSESSED ACTIVE SITES & IMPOUNDMENTS

| State | Agricultural Sites | Agricultural Imps | Municipal Sites | Municipal Imps | Industrial Sites | Industrial Imps | Mining Sites | Mining Imps | Oil & Gas Sites | Oil & Gas Imps | Other Sites | Other Imps | Total Sites | Total Imps |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KY | 60 | 130 | 186 | 250 | 141 | 255 | 121 | 151 | 109 | 118 |  |  | 617 | 904 |
| LA |  |  | 70 | 70 | 204 | 204 | 2 | 2 | 41 | 41 |  |  | 317 | 317 |
| MA | 3 | 3 | 138 | 139 | 75 | 75 |  |  |  |  |  |  | 216 | 217 |
| MD | 68 | 69 | 79 | 79 | 122 | 122 | 128 | 128 |  |  |  |  | 397 | 398 |
| ME | 28 | 28 | 56 | 56 | 48 | 48 |  |  |  |  |  |  | 132 | 132 |
| MI | 82 | 82 | 117 | 117 | 167 | 167 | 23 | 23 |  |  |  |  | 389 | 389 |
| MN | 673 | 751 | 378 | 844 | 110 | 279 | 5 | 8 |  |  |  |  | 1166 | 1882 |
| MO | 827 | 827 | 652 | 652 | 272 | 272 | 45 | 45 |  |  |  |  | 1796 | 1796 |
| MS | 157 | 157 | 189 | 189 | 363 | 365 | 5 | 5 | 5 | 5 |  |  | 719 | 721 |
| MT | 18 | 18 | 33 | 33 | 39 | 39 | 14 | 14 | 48 | 48 |  |  | 152 | 152 |
| NC | 76 | 76 | 241 | 241 | 327 | 327 | 13 | 13 |  |  |  |  | 657 | 657 |
| ND | 248 | 287 | 360 | 739 | 8 | 26 | 25 | 65 | 23 | 23 |  |  | 664 | 1140 |
| NE | 30 | 30 | 48 | 48 | 70 | 71 | 1 | 1 | 22 | 22 |  |  | 171 | 172 |
| NH | 15 | 22 | 107 | 202 | 30 | 59 |  |  |  |  |  |  | 152 | 283 |
| NJ | 2 | 2 | 39 | 39 | 126 | 172 | 7 | 7 |  |  |  |  | 174 | 220 |
| NM | 4 | 4 | 98 | 98 | 40 | 40 | 73 | 73 |  |  |  |  | 215 | 215 |
| NV | 2 | 2 | 14 | 16 | 12 | 15 | 9 | 9 |  |  |  |  | 37 | 42 |
| NY | 14 | 14 | 43 | 43 | 92 | 93 | 1 | 1 | 20 | 20 |  |  | 170 | 171 |

## ASSESSED ACTIVE SITES & IMPOUNDMENTS

| State | Agricultural Sites | Agricultural Imps | Municipal Sites | Municipal Imps | Industrial Sites | Industrial Imps | Mining Sites | Mining Imps | Oil & Gas Sites | Oil & Gas Imps | Other Sites | Other Imps | Total Sites | Total Imps |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OH | 128 | 128 | 430 | 430 | 806 | 807 | 133 | 134 | 1200 | 1200 | | | 2697 | 2699 |
| OK | 49 | 50 | 63 | 63 | 145 | 148 | 35 | 36 | 151 | 151 | | | 443 | 448 |
| OR | 55 | 55 | 207 | 213 | 90 | 90 | 11 | 11 | | | | | 363 | 369 |
| PA | 242 | 243 | 398 | 401 | 652 | 1021 | 124 | 129 | 116 | 116 | 294 | 294 | 1826 | 2204 |
| PR | 102 | 102 | 2 | 2 | 16 | 16 | | | | | | | 120 | 120 |
| RI | 9 | 17 | 8 | 24 | 27 | 88 | | | | | | | 44 | 129 |
| SC | 921 | 955 | 579 | 731 | 200 | 390 | 2 | 2 | | | | | 1702 | 2078 |
| SD | 278 | 334 | 267 | 475 | 18 | 50 | 4 | 14 | 27 | 31 | | | 594 | 904 |
| TN | 41 | 41 | 20 | 20 | 147 | 148 | 17 | 17 | | | | | 225 | 226 |
| TT | | | 3 | 3 | | | | | | | | | 3 | 3 |
| TX | 50 | 51 | 110 | 110 | 610 | 610 | 28 | 28 | 103 | 103 | | | 901 | 902 |
| UT | 5 | 7 | 39 | 169 | 29 | 79 | 3 | 10 | 128 | 128 | | | 204 | 393 |
| VA | 20 | 21 | 34 | 34 | 87 | 87 | 11 | 11 | | | | | 152 | 153 |
| VI | | | 7 | 7 | 2 | 2 | | | | | | | 9 | 9 |
| VT | 127 | 129 | 61 | 93 | 19 | 41 | 1 | 3 | | | | | 208 | 266 |
| WA | 17 | 22 | 25 | 57 | 85 | 446 | 2 | 10 | | | | | 129 | 535 |
| WI | 200 | 200 | 199 | 199 | 202 | 202 | 5 | 5 | | | | | 606 | 606 |
| WV | 12 | 14 | 314 | 394 | 99 | 326 | 37 | 274 | | | | | 462 | 1008 |
| WY | 6 | 6 | 29 | 29 | 29 | 29 | 13 | 14 | 357 | 359 | | | 434 | 437 |

## APPENDIX B-III

## LOCATED ABANDONED SITES & IMPOUNDMENTS

| State | Agricultural | | Municipal | | Industrial | | Mining | | Oil & Gas | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps |
| AK | 1 | 1 | 26 | 30 | | | | | | | | | 27 | 31 |
| AL | | | | | | | | | | | | | | |
| AR | | | 2 | 10 | 10 | 14 | | | | | | | 12 | 24 |
| AS | | | | | | | | | | | | | | |
| AZ | 1 | 8 | 13 | 33 | | | 6 | 7 | | | | | 20 | 48 |
| CA | 3 | 5 | 10 | 37 | 4 | 9 | 1 | 5 | 12 | 19 | 1 | 26 | 31 | 101 |
| CO | | | | | | | | | | | | | | |
| CT | 1 | 1 | 16 | 63 | 65 | 121 | 1 | 3 | | | | | 83 | 188 |
| DE | | | | | | | | | | | | | | |
| FL | | | | | | | | | | | | | | |
| GA | 12 | 12 | 49 | 50 | 3 | 7 | 1 | 1 | | | | | 65 | 70 |
| GM | | | | | | | | | | | | | | |
| HI | | | | | | | | | | | | | | |
| IA | | | | | | | | | | | | | | |
| ID | | | | | | | | | | | | | | |
| IL | 5 | 6 | 88 | 134 | 69 | 139 | 16 | 28 | 413 | 438 | | | 591 | 745 |
| IN | | | | | | | | | | | | | | |
| KS | | | | | | | | | | | | | | |

## LOCATED ABANDONED SITES & IMPOUNDMENTS

| State | Agricultural Sites | Agricultural Imps | Municipal Sites | Municipal Imps | Industrial Sites | Industrial Imps | Mining Sites | Mining Imps | Oil & Gas Sites | Oil & Gas Imps | Other Sites | Other Imps | Total Sites | Total Imps |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KY | | | | | | | | | | | | | | |
| LA | | | 1 | 1 | 20 | 39 | | | 28 | 37 | | | 49 | 77 |
| MA | 1 | 6 | 18 | 142 | 8 | 25 | | | | | 6 | 35 | 33 | 208 |
| MD | | | 1 | 1 | 12 | 24 | | | | | | | 13 | 25 |
| ME | 3 | 3 | 13 | 16 | 23 | 111 | 2 | 3 | | | | | 41 | 133 |
| MI | 2 | 2 | 6 | 10 | 63 | 114 | | | | | 5 | 9 | 76 | 135 |
| MN | 2 | 2 | 11 | 13 | 18 | 29 | 104 | 116 | | | | | 135 | 160 |
| MO | 4 | 4 | 250 | 250 | 221 | 221 | 4 | 4 | | | 28 | 28 | 507 | 507 |
| MS | 47 | 52 | 5 | 6 | | | | | | | | | 52 | 58 |
| MT | | | | | | | | | | | | | | |
| NC | 1 | 1 | 6 | 6 | 15 | 15 | 4 | 8 | | | | | 26 | 30 |
| ND | | | | | | | | | | | | | | |
| NE | | | | | | | | | | | | | | |
| NH | | | 1 | 1 | 1 | 3 | | | | | | | 2 | 4 |
| NJ | 3 | 5 | 6 | 24 | 37 | 100 | | | | | | | 46 | 129 |
| NM | 2 | 3 | 18 | 47 | 9 | 32 | 7 | 10 | 3 | 24 | | | 39 | 116 |
| NV | | | | | 4 | 264 | 6 | 118 | | | | | 10 | 382 |
| NY | | | 7 | 8 | 33 | 44 | | | | | | | 40 | 52 |

## LOCATED ABANDONED SITES & IMPOUNDMENTS

| State | Agricultural | | Municipal | | Industrial | | Mining | | Oil & Gas | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps |
| OH | | | | | | | | | | | | | | |
| OK | | | | | | | | | | | | | | |
| OR | | | | | | | | | | | | | | |
| PA | 7 | 17 | 18 | 30 | 130 | 395 | 60 | 97 | 6 | 18 | 13 | 70 | 234 | 627 |
| PR | | | | | | | | | | | | | | |
| RI | | | | | 3 | 13 | | | | | | | 3 | 13 |
| SC | | | | | | | | | | | | | | |
| SD | | | | | | | | | | | | | | |
| TN | 9 | 12 | 1 | 1 | 47 | 136 | 1 | 1 | 1 | 1 | | | 59 | 151 |
| TT | | | | | | | | | | | | | | |
| TX | 60 | 120 | 31 | 54 | 79 | 191 | | | | | | | 170 | 365 |
| UT | | | | | | | | | | | | | | |
| VA | 4 | 4 | 13 | 19 | 8 | 15 | 5 | 24 | | | | | 30 | 62 |
| VI | | | | | | | | | | | | | | |
| VT | 1 | 1 | 4 | 4 | 5 | 12 | | | | | | | 10 | 17 |
| WA | | | | | | | | | | | | | | |
| WI | 2 | 2 | 2 | 2 | 42 | 67 | 3 | 11 | | | | | 49 | 82 |
| WV | 2 | 3 | 14 | 14 | 8 | 19 | 42 | 150 | | | | | 66 | 186 |
| WY | | | | | | | | | | | | | | |

## APPENDIX B-IV

## ASSESSED ABANDONED SITES & IMPOUNDMENTS

| State | Agricultural | | Municipal | | Industrial | | Mining | | Oil & Gas | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps |
| AK | | | 5 | 5 | | | | | | | | | 5 | 5 |
| AL | | | | | | | | | | | | | | |
| AR | | | 2 | 2 | 10 | 10 | | | | | | | 12 | 12 |
| AS | | | | | | | | | | | | | | |
| AZ | | | | | | | | | | | | | | |
| CA | 3 | 3 | 10 | 13 | 3 | 3 | 1 | 1 | 10 | 14 | 1 | 3 | 28 | 37 |
| CO | | | | | | | | | | | | | | |
| CT | 1 | 1 | 16 | 16 | 62 | 63 | 1 | 1 | | | | | 80 | 81 |
| DE | | | | | 4 | 4 | | | | | | | 4 | 4 |
| FL | | | | | | | | | | | | | | |
| GA | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 4 | 4 |
| GM | | | | | | | | | | | | | | |
| HI | | | | | | | | | | | | | | |
| IA | | | | | | | | | | | | | | |
| ID | | | | | | | | | | | | | | |
| IL | 5 | 5 | 21 | 21 | 69 | 69 | 16 | 16 | 30 | 30 | | | 141 | 141 |
| IN | | | | | | | | | | | | | | |
| KS | | | | | | | | | | | | | | |

# ASSESSED ABANDONED SITES & IMPOUNDMENTS

| State | Agricultural | | Municipal | | Industrial | | Mining | | Oil & Gas | | Other | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps | Sites | Imps |
| KY | | | | | | | | | | | | | | |
| LA | | | 1 | 1 | 19 | 19 | | | 3 | 3 | | | 23 | 23 |
| MA | 1 | 1 | 13 | 13 | 6 | 6 | | | | | 6 | 6 | 26 | 26 |
| MD | | | 1 | 1 | 4 | 4 | | | | | | | 5 | 5 |
| ME | 3 | 3 | 13 | 13 | 22 | 22 | 2 | 2 | | | | | 40 | 40 |
| MI | | | 3 | 3 | 27 | 27 | | | | | 4 | 4 | 34 | 34 |
| MN | 2 | 2 | 11 | 13 | 18 | 29 | 14 | 14 | | | | | 45 | 58 |
| MO | | | | | | | | | | | | | | |
| MS | 14 | 14 | 4 | 4 | | | | | | | | | 18 | 18 |
| MT | | | | | | | | | | | | | | |
| NC | 1 | 1 | 6 | 6 | 15 | 15 | 4 | 4 | | | | | 26 | 26 |
| ND | | | | | | | | | | | | | | |
| NE | | | | | | | | | | | | | | |
| NH | | | 1 | 1 | 1 | 3 | | | | | | | 2 | 4 |
| NJ | 2 | 2 | 3 | 3 | 25 | 25 | | | | | | | 30 | 30 |
| NM | | | 5 | 5 | 4 | 4 | 4 | 4 | 1 | 1 | | | 14 | 14 |
| NV | | | | | 2 | 3 | 3 | 4 | | | | | 5 | 7 |
| NY | | | 1 | 1 | 2 | 2 | | | | | | | 3 | 3 |

## ASSESSED ABANDONED SITES & IMPOUNDMENTS

| State | Agricultural Sites | Agricultural Imps | Municipal Sites | Municipal Imps | Industrial Sites | Industrial Imps | Mining Sites | Mining Imps | Oil & Gas Sites | Oil & Gas Imps | Other Sites | Other Imps | Total Sites | Total Imps |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OH | | | | | | | | | | | | | | |
| OK | | | | | | | | | | | | | | |
| OR | | | | | | | | | | | | | | |
| PA | 7 | 7 | 17 | 17 | 128 | 197 | 56 | 56 | 6 | 6 | 12 | 13 | 226 | 296 |
| PR | | | | | | | | | | | | | | |
| RI | | | | | 3 | 13 | | | | | | | 3 | 13 |
| SC | | | | | | | | | | | | | | |
| SD | | | | | | | | | | | | | | |
| TN | | | | | | | | | | | | | | |
| TT | | | | | | | | | | | | | | |
| TX | 7 | 7 | 8 | 8 | 11 | 11 | | | | | | | 26 | 26 |
| UT | | | | | | | | | | | | | | |
| VA | | | | | 2 | 2 | | | | | | | 2 | 2 |
| VI | | | | | | | | | | | | | | |
| VT | 1 | 1 | 4 | 4 | 5 | 12 | | | | | | | 10 | 17 |
| WA | | | | | | | | | | | | | | |
| WI | 1 | 1 | 1 | 1 | 20 | 20 | 2 | 2 | | | | | 24 | 24 |
| WV | | | | | 6 | 14 | | | | | | | 6 | 14 |
| WY | | | | | | | | | | | | | | |

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